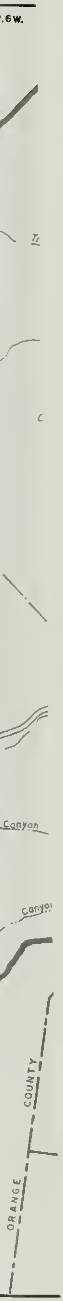
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Planned Utilization of Water Resources in Ventura County

Bulletin
No. 104-8

November 1976

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Department of
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Bulletin No. 104-8

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November 1976

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Edmund G. Brown Jr.
Governor

State of
California

Ronald B. Robie
Director

Department of
Water Resources

CONVERSION FACTORS

English to Metric System of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)	25.4	millimetres (mm)
		.0254	metres (m)
	feet (ft)	.3048	metres (m)
	miles (mi)	1.6093	kilometres (km)
Area	square inches (in^2)	6.4516×10^{-4}	square metres (m^2)
	square feet (ft^2)	.092903	square metres (m^2)
	acres	4046.9	square metres (m^2)
		.40469	hectares (ha)
		.40469	square hectometres (hm^2)
		.0040469	square kilometres (km^2)
	square miles (mi^2)	2.590	square kilometres (km^2)
Volume	gallons (gal)	3.7854	litres (l)
		.0037854	cubic metres (m^3)
	million gallons (10^6 gal)	3785.4	cubic metres (m^3)
	cubic feet (ft^3)	.028317	cubic metres (m^3)
	cubic yards (yd^3)	.76455	cubic metres (m^3)
	acre-feet (ac-ft)	1233.5	cubic metres (m^3)
		.0012335	cubic hectometres (hm^3)
		1.233×10^{-6}	cubic kilometres (km^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
		.028317	cubic metres per second (m^3/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
		6.309×10^{-5}	cubic metres per second (m^3/s)
	million gallons per day (mgd)	.043813	cubic metres per second (m^3/s)
Mass	pounds (lb)	.45359	kilograms (kg)
	tons (short, 2,000 lb)	.90718	tonne (t)
		907.18	kilograms (kg)
Power	horsepower (hp)	0.7460	kilowatts (kW)
Pressure	pounds per square inch (psi)	6894.8	pascal (Pa)
Temperature	Degrees Fahrenheit (°F)	$\frac{tF - 32}{1.8} = tC$	Degrees Celsius (°C)

FOREWORD

At present, nearly half the water supply of Southern California's coastal area comes from storage in its ground water basins. The remainder comes from limited surface storage and diversions and increasing amounts of imported water.

The Department of Water Resources, recognizing the need for local agencies to implement water management plans involving numerous supply sources, has undertaken a series of comprehensive investigations in cooperation with local agencies to formulate such plans to satisfy the future water demand.

In Ventura County, where the relative importance of ground water storage is even greater than that of the region as a whole, two conditions have developed that have caused alarm among some of the local agencies regarding their ability to continue to meet the demand for water. One is the direct result of declining ground water levels: sea water has been drawn into portions of one of the underlying coastal aquifer systems. The second is the increasing mineralization of ground water.

Because of the fears raised by these conditions, the Ventura County Flood Control District entered into a cooperative agreement with the Department of Water Resources to conduct an investigation to develop information on which to base a sound water resources management program for 1970-2020. In this investigation, comprehensive studies were made of geology, hydrology, water quality, and operation-economics of the major ground water basins in Ventura County. To determine the effects of operating various management alternatives on the quantity and quality of water in the basins, mathematical models of the basins were developed.

This bulletin summarizes the results of those studies. The publications listed in the bibliography at the back of the bulletin contain some of the detailed information supporting this report; they, plus other supporting data, are available for inspection in the office of the Southern Division, Department of Water Resources, Los Angeles.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
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I. INTRODUCTION AND SUMMARY

The coastal plain of Ventura County has long been a major agricultural producer with a ready market in the Los Angeles metropolitan area to the southeast of it. It has maintained its production even though population has, since the early 1960s, been pushing over the county line and transforming many of the County's small rural communities into urban centers of residences and light industry.

Although the population growth has leveled off within the past few years, the change has been so rapid that public utility and other service agencies have been concerned about their ability to keep pace.

For the suppliers of water, much of the increased demand has been met by pumping more ground water. In some cases, this has required the use of water of high mineral content and the lowering of the water table to below sea level, which has drawn sea water into the Oxnard Plain Basin. Fear has been expressed that the ground water will be so degraded that Ventura County will be unable to meet its anticipated future water demand.

Objective of Investigation

Recognizing this concern, the Ventura County Flood Control District entered into a cooperative study with the California Department of Water Resources to develop information needed by the water suppliers in planning their future course of action. The selected period to be covered was 1970 to 2020.

The overall objective was to estimate future water demand, inventory available water supplies and facilities, and analyze a number of management alternatives -- giving emphasis to

Photo courtesy Ventura Regional County Sanitation District

TRUCK CROPS, which depend upon irrigation water, are an important industry on the Oxnard Plain.

ground water resources -- so that the most economical and environmentally acceptable choices can be identified.

This is one of three studies dealing with water resources in Ventura County that have been undertaken in the past several years. In one, still being conducted by the U. S. Bureau of Reclamation, emphasis has been on the possible use of reclaimed water as a supply source. Another is the study leading to the Water Quality Control Plan, Santa Clara River Basin,[7*] adopted by the Regional Water Quality Control Board, Los Angeles Region, and approved by the State Water Resources Control Board.

These three studies provide the foundation for a water resources management program for Ventura County. As Figure 1 shows, responsible local agencies, by analyzing the institutiona, legal, and political aspects of the mos promising features of the management alternatives, should have sufficient information upon which to base a decisi on the most economical and effective management plan for Ventura County.

The next step will be to develop an implementation schedule--providing not only time and financing for carrying out the physical features, but also bringing about institutional and legal changes needed to implement the selected management plan.

Area of Investigation

Ventura County lies along the Pacific Coast, between Santa Barbara and Los Angeles Counties. Kern County adjoins it on the north (Figure 2).

---

* Numbers in superscript refer to reports listed in the Bibliography, which is bound at the back of the bulletin.

Figure 1
WATER RESOURCES MANAGEMENT PROGRAM
Steps Involved

From studies by State, Federal, and local agencies	*1. Projection of future water demand* *2. Inventory of water supplies and facilities* *3. Formulation of management alternatives for meeting future demand* *4. Physical and economic analysis of alternatives (includes preliminary assessment of secondary effects on significant elements of environment)*
To be completed by local agencies	*5. Legal, institutional, and political evaluation of most promising management alternatives* *6. Selection of a management plan* *7. Development of an implementation schedule* *a. Provision for funding* *b. Creation of necessary institutional and legal conditions* *c. Preparation of EIR on needed major facilities* *8. Implementation of selected management plan*

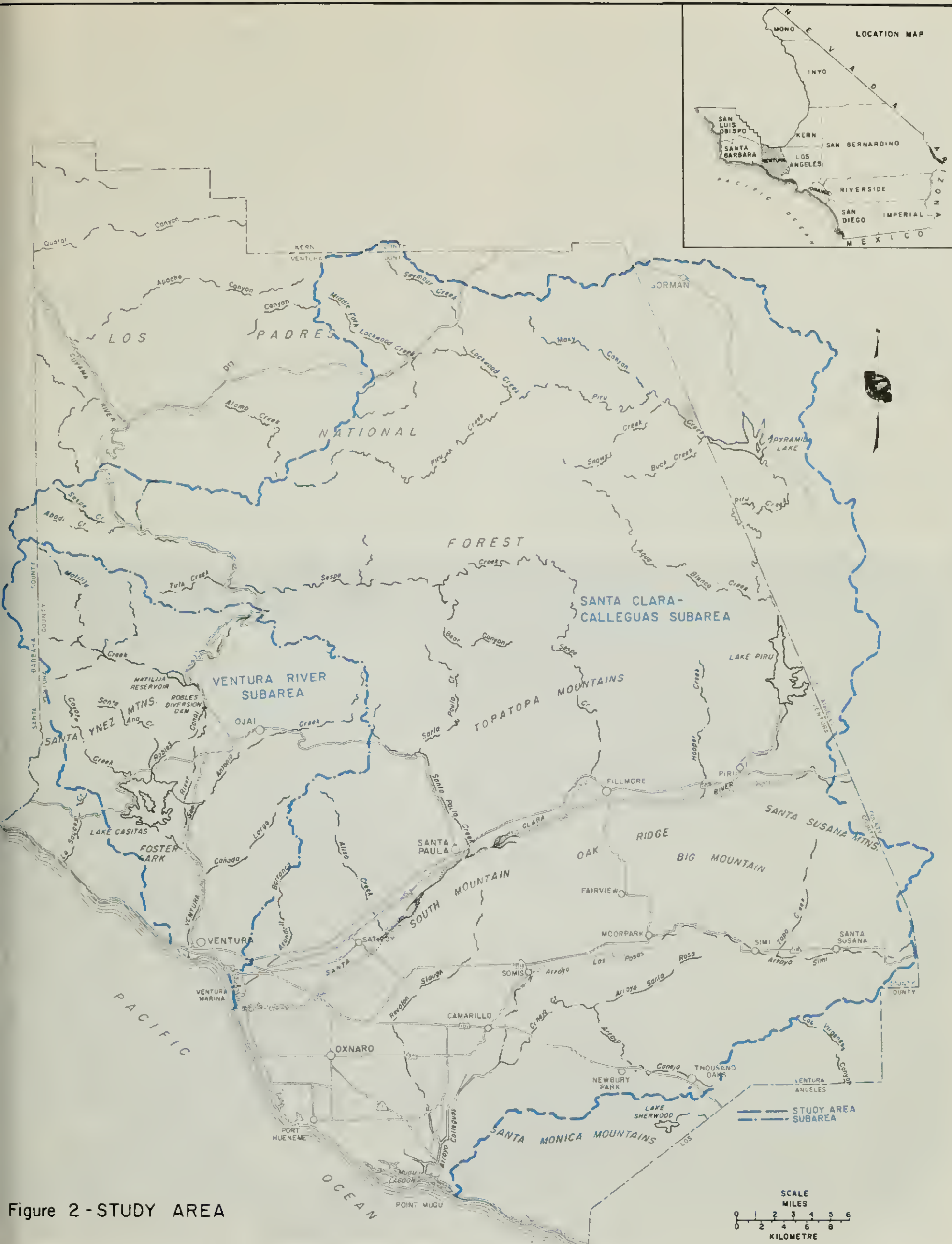


Figure 2 - STUDY AREA

DEPARTMENT OF WATER RESOURCES, SOUTHERN DIVISION, 1976

The terrain in the northern portion of Ventura County is mountainous; therefore, the population is sparse. Toward the central and southern portions, the mountains are lower and are cut by alluvial valleys. The population has congregated here and on the coastal plain (known as the Oxnard Plain) in the south.

Three principal stream systems--Ventura River, Santa Clara River, and Calleguas Creek--drain into the Pacific Ocean. The natural flow in all three streams is intermittent, dependent largely upon the rainfall, which is mainly confined to the winter months.

In 1970, the population of Ventura County was 374,000, an increase of 90 percent over the 199,000 in 1960. The 1975 population was 432,000. Along with the population, residential, commercial, an industrial developments have also increased, although agriculture (mainly citrus, subtropical, and truck crops) has continued to be economically important. The largest population centers are Oxnard, San Buenaventura (Ventura), Thousand Oaks, Simi Valley, Port Hueneme, Ojai, Fillmore, Santa Paula, and Camarillo.

Three major water wholesale agencies supply the area: Casitas Municipal Water District, Calleguas Municipal Water District, and United Water Conservation District (Figure 3). These agencies sell water to the many purveyors that sell directly to the public.

Seventy-five percent of the population is served by sewerage systems.

Photo courtesy United Water Conservation District

SANTA PAULA is one of the communities lying in the Santa Clara River Valley.

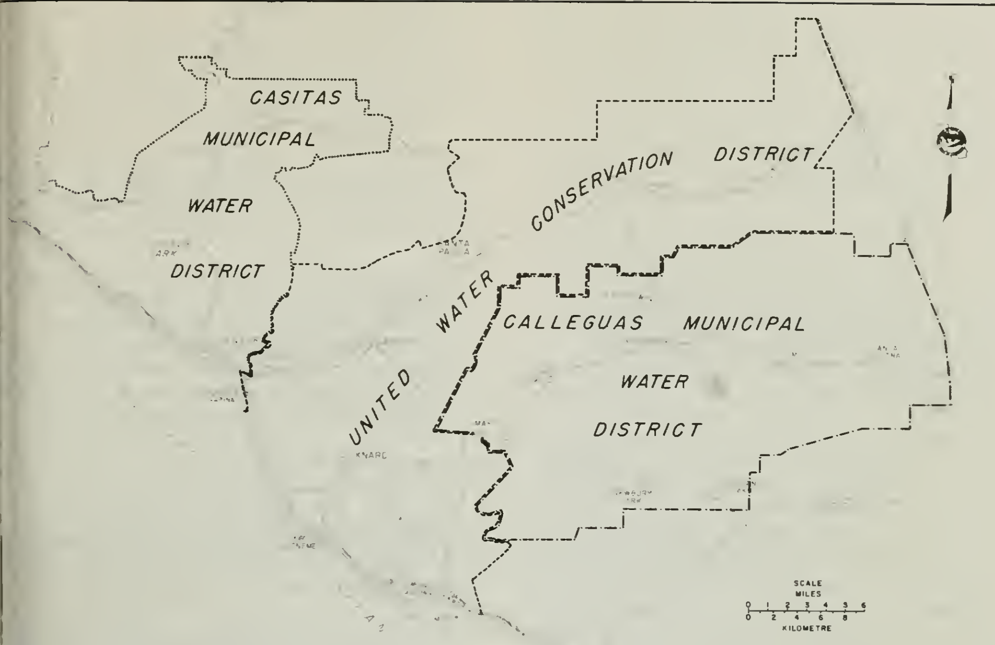


Figure 3 - SERVICE AREAS OF MAJOR WATER AGENCIES

Scope and Conduct of Investigation

To ensure that the cooperative study remained responsive to the needs and concerns of Ventura County, a Technical Coordinating Committee, composed of representative water leaders of the county, met regularly with the Department of Water Resources investigators.

Although runoff from the northern, mountainous portion of the county contributes significantly to the water supply, the study area--for operational purposes--was limited to the populous portions in the southern half of the county.

For convenience, the study area was divided into two subareas according to the stream systems that drain them--the Santa Clara-Calleguas Subarea and the Ventura River Subarea.

The management choices given in this report apply only to the Santa Clara-Calleguas Subarea. At this time, a study of conjunctive use of ground water with surface water facilities in the Ventura River Subarea is being considered by the Ventura County Flood Control District and the Casitas Municipal Water District. The study reported here was conducted in five phases: geology, hydrology, operation, water quality, and economics. From the first two phases came the information needed on locally available and usable water supplies so that the investigators could develop practical management alternatives and study them in the last three phases.

Because of the complexity of the ground water basins in the Santa Clara-Calleguas Subarea, mathematical models were constructed to depict water quantity and quality in those basins that contain usable supplies.[6,34] By means of these models, the quality and water level elevations in the basins could be determined under operation of each of the management alternatives studied.

Of the many possible options, five were selected by the Technical Coordinating Committee for detailed operational-economic study and were designated A through E. They were selected because they represent the extremes of management choices--i.e., use as much ground water as possible, use as much imported water as possible, use only as much from the ground water basins as is returned to them, and use ground water and imported water for only specific beneficial purposes. It should be recognized, however, that the management plan which is ultimately chosen for implementation by the local agencies will most likely be a modification of the five management alternatives presented here. As one example, the investigators prepared a modification that incorporates some of the most promising features of the original five alternatives. This modification was designated alternative L.

Summary of Findings

The estimate of future water demand and inventory of available water supplies and facilities in Ventura County, which were made as part of this study, revealed that:

1. Although water demand cannot be projected with complete reliability, all projections made by various agencies show an increase for Ventura County between 1970 and 2020. For this study, the 314,000 acre-feet (387 cubic hectometres--hm^3) being used in 1970 was estimated to increase to 536,000 acre-feet (661 hm^3) by 2020.

2. Supplies available to the county to meet the expected increase in demand are surface water, reclaimed water, imported water, and ground water. Under current conditions, little variation is expected in the amount of surface water that could be used. The amou of reclaimed water that will be use cannot be projected with certainty.

3. The amount of water being imported could be increased. One of the water agencies in Ventura County (Calleguas Municipal Water District, which is a member of The Metropolit Water District of Southern Californ has already begun importing water, and the amount imported could be increased. Indications are this wa will be from the State Water Projec only. In addition, other Ventura County agencies hold entitlements t 20,000 acre-feet (24 hm^3) annually of State Water Project water.

4. The average quality of water (measu in total dissolved solids--TDS--content) imported through the State Water Project is better than the average quality of ground water pum in the Oxnard Plain. In 1974, the average TDS content of water importe from the State Water Project was le than 300 milligrams per litre (mg/l) that of ground water pumped in the Oxnard Plain in 1975, was 1 060 to 1 070 mg/l.

5. The ground water basins along the Ventura River contain an estimated 89,000 acre-feet (110 hm^3) of water; those in the vicinity of the Santa Clara River and Calleguas Creek contain 29,000,000 acre-feet (36 000 hm^3).

6. The aquifer zones of the Oxnard Plain form virtually two separate systems. The upper system is the major water-producing system now being used; however, a portion of it has been intruded by sea water. Indications are that the lower

MATHEMATICAL MODELS: VALUABLE TOOLS FOR ANALYSIS

How does one determine ahead of time how a ground water basin might react if it is managed according to a certain plan? In other words, how can one estimate what will be the quantity and quality of ground water in a basin at some time in the future?

The key is that the quantity of water contained in a ground water basin is indicated by the elevation of the level of the water; the quality by the TDS content of the water pumped from the basin.

This information is obtained by the use of a series of mathematical equations that express the transmissive and storage capabilities of the basin. Also required are data on quantity and quality of all water supplies going into the basin and all extractions or other removals from the basin under the proposed management plan.

Because the basins in the Santa Clara-Calleguas Subarea are large, the physical characteristics within each basin vary greatly. Therefore, each basin was divided into polygons, or sections, as shown in Figure 4. The geology and hydrology of each polygon were then examined to ascertain the physical effects of each management alternative.

Thus, the determination of quantity of water under each management alternative called for the simultaneous solving of some 160 separate equations. The analysis of water quality involved still more equations. Consequently, an electronic computer was used to solve the equations for both the quantity and quality analyses. In effect, mathematical models represented ground water basins.

Water quantity models have been used in a number of other investigations, and their construction and operation have been improved with use. Ground water quality models, however, were, prior to this study, largely experimental.

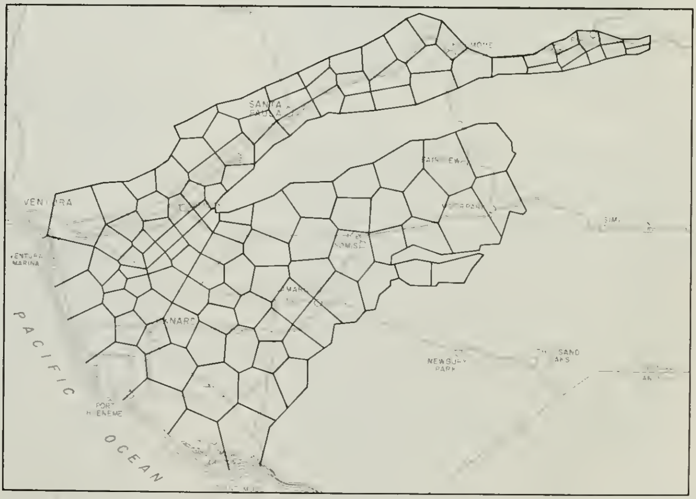
Fortunately for this study, the Department of Water Resources, under a grant from the Office of Water Resources Research of the U. S. Department of the Interior, has developed a usable two-layer water quality model of the ground water basins in Ventura County. This model was used to obtain an estimate of future TDS content of the ground water pumped under operation of each of the management alternatives studied.

An idea of the process of constructing, verifying, and operating the mathematical models used in this investigation can be obtained from a study of "Mathematical Modeling of Water Quality for Water Resources Management"[6] and the technical information records[34] contributing to it.

Both the quantity and quality models developed in this study can be used by Ventura County water leaders for analysis of possible modifications to the management alternatives. They will thus be spared the additional time and expense required to develop workable water quantity and quality models of their ground water basins.

Figure 4

POLYGONS USED IN MATHEMATICAL MODELS



system extends several miles offshore and contains in its undersea extension an estimated 5 to 8 million acre-feet (6 000 to 10 000 hm^3) of fresh water. Perhaps more than half of this is recoverable by means of onshore wells.

7. The quality of water pumped from the Lower Aquifer System is, in general, of better quality than that pumped from the Upper Aquifer System of the Oxnard Plain. The average TDS content of water pumped from the Lower Aquifer System was approximately 800 mg/l in 1970; that from the Upper Aquifer System was approximately 1 000 mg/l in 1970.

8. Currently, recharge of the Upper Aquifer System is primarily from two spreading grounds north of the Oxnard Plain. The amount of water that could be percolated through the spreading grounds could be increased. Because of the flat water table gradient and the shallowness of the sediments, water moves outward from the spreading grounds through the aquifers very slowly. The Lower Aquifer System is also replenished from these spreading grounds, but another potential recharge area for this system lies on the south flank of South Mountain.

9. The aquifer zones supplying water in the Santa Clara River Valley, Pleasant Valley, and East and West Las Posas areas (all within the Santa Clara-Calleguas Subarea) tend to form a single producing system. The aquifer zones under the Santa Clara River Valley are in hydraulic continuity with the aquifer zones of the Oxnard Plain Basin. Those forming the East and West Las Posas Basins and the Pleasant Valley Basin are in hydraulic continuity with only the lower system of the Oxnard Plain.

The analysis of five water managment alternatives for Ventura County and a preliminary study of a modification using their most promising features showed that:

1. The available supplies could be managed in a number of different ways to produce enough water to meet the projected demand to the year 2020.

2. Sea water intrusion could be controlled in the Upper Aquifer System of the Oxnard Plain by: (a) limiting the amount of water pumped to approximately the amount naturally returning to the basin, (b) recharging the Upper Aquifer System with a large amount of imported water plus shifting the pumping pattern inland from the coast and using more water from the Lower Aquifer System, (c) developing a sea water "barrier by injection wells, or (d) shifting all pumping in the Oxnard Plain to

TDS CONTENT OF WATER--
WHAT DOES IT MEAN?

Water quality is an elusive thing. Absolutely pure water (distilled water) is unpalatable because it is tasteless. The introduction of proper amounts of salts--including common table salt (sodium chloride)--and other minerals adds flavor and makes it "fresh".

But if too much of these salts is added, we say the water "tastes". If the water is applied to crops, it may result in a salt buildup around the root zone, which limits yield unless extra water is applied to leach it out.

Thus, the amounts of these salts and minerals in the water have come to be regarded as an indicator of the quality of the water. A reading is taken by evaporating a sample of water; the residue represents the total solids that had been dissolved in the water. Hence, the term, total dissolved solids (TDS for short). This is measured in milligrams per litre--a milligram of salt in a litre of water is roughly equivalent to two or three grains of salt in a quart (.9463 litre) of water.

the Lower Aquifer System. Further intrusion could be stopped by 1978 to 1990, depending upon the method used.

3 The water used for agriculture under most of the management alternatives studied would have about the same TDS content as does the water which is being used now for agriculture in Ventura County (average TDS of present agriculture water is 690 to 1 310 mg/l). Yields of citrus, subtropical, and truck crops are being maintained with water of this TDS content by increasing the amounts of water applied to leach the salts out of the root zone.

4. Under operation of most alternatives, some water would move from the coastal portion of the Upper Aquifer System to the ocean, both as subsurface flow and as stream flow fed by rising water and flood runoff.

5. Comparison of costs of various management alternatives cannot be reliably made until better data and procedures have been developed for evaluating the cost to the users of poor quality water.

6. All management alternatives would call for commitment of resources to such undertakings as the drilling or deepening of wells and the construction of pipelines.

7. Importation of water into Ventura County through the State Water Project would require the expenditure of significantly more energy than would pumping the same amount of water from the Lower Aquifer System of the Oxnard Plain.

Conclusions

From the findings made in this study, the following conclusions were drawn:

1. With proper management of the available water resources, future water demand in Ventura County can be met. The most desirable management plan--from all standpoints--would be a modification of one of the five management alternatives studied in detail.

2. The sea water intrusion front, which had moved two to three miles (3 to 5 kilometres) into the Upper Aquifer System of the Oxnard Plain by 1974, can be moved back to the shoreline. However, under any of the management alternatives considered, this would require a number of decades. Control of the intrusion could not be achieved by spreading large amounts of water at the existing spreading grounds, unless a shift in pumping pattern (inland and to the lower system) accompanied the spreading.

3. Increased pumping from the Lower Aquifer System in the Oxnard Plain would make possible the use of the fresh water stored in the offshore portion of the system. This water could be used for more than 30 years with proper management, which includes the use of monitoring wells to detect the presence of sea water early enough that facilities could be provided for shifting to another water source.

4. Increased pumping from the Lower Aquifer System in the Oxnard Plain could also be reflected in lower water levels in the Pleasant Valley and East and West Las Posas Basins, where the main producing aquifer zone is in hydraulic continuity with the lower system of the Oxnard Plain. However, the cost saving that would be realized from use of water from the Lower Aquifer System, rather than an equal amount of imported water, would be great enough to permit the compensation of pumpers in those basins for their added pumping cost.

5. Further savings could be realized by:

   a. Reducing the size of the water demand through encouraging the conservation of water, both among urban and agricultural users.

   b. Using reclaimed water for irrigation, where possible. For example, if the water in the Upper Aquifer System of the Oxnard Plain that is downgradient from the present spreading grounds could be used exclusively for irrigation, reclaimed water could immediately be used for replenishment. This would be possible because the concern of the Department of Health regarding replenishment of ground water basins with reclaimed water applies only to those basins used for domestic supplies.

   c. Continuing to use water of high TDS content for irrigating crops in the Oxnard Plain, as has been done in the past. The use of this water will stretch the available local supply and minimize the need for imported water.

6. For the determination of the most economical plan, additional information is needed, especially with regard to the cost associated with the use of poor quality water (water quality "penalty" cost).

Recommendations

Therefore, the following recommendations are made:

1. Before a final management decision is made, additional information be developed on water quality "penalty" costs and water agencies in Ventura County examine in detail the modified management alternative presented in this report and any other modifications they feel are worthy of consideration to ensure that the management program they adopt is indeed the most favorable one for their area.

2. Consideration be given to ways in which water conservation can be encouraged for both urban and agricultural uses in Ventura County, and a specific educational program be implemented to encourage conservation.

3. Ventura County expand its use of reclaimed water where proved beneficial, considering health hazards, availability, and markets.

4. The use of water of high TDS content be continued for agriculture as long as it is economical and serves the beneficial uses.

II. WATER DEMAND AND SUPPLIES

Basic to any water resources management program are an estimate of the anticipated future demand for water and an inventory of the available supplies and facilities for meeting that demand. To develop information required for the inventory of water supplies, the geologic and hydrologic phases of the study were carried out.

Estimating Future Demand

Water demand is affected by many factors; one of these is an increased concern with water conservation. Another is a change in agricultural acreage.

Predicting which factors will be influential at some time in the future is almost impossible to do with any degree of accuracy. Therefore, the projections made by different agencies--and even by the same agency at different times--may show considerable variation.

For example, two recent studies, both using the same population growth rate,* projected different water demands in Ventura County in year 2000. The Department of Water Resources Bulletin No. 160-74, "The California Water Plan: Outlook in 1974," forecasts a demand of 360,000 acre-feet (444 cubic hectometres--hm^3) per year in 2000, while the Water Quality Control Plan, Santa Clara River Basin,[7] forecasts a demand of 450,000 acre-feet (555 hm^3) per year.

When the Water Quality Control Plan is adopted, it will become part of the California Water Plan. Recognizing this fact, the Technical Coordinating Committee agreed that the water demand projections contained in the Water Quality Control Plan should be used for the study reported here. Thus, the projected demand is 536,000 acre-feet (661 hm^3) by year 2020; up from the 314,000 acre-feet (387 hm^3) in 1970 (Figure 5).

For this forecast, agricultural acreage in 1970 was estimated to be 110,200 acres (44 597 hectares--ha) and was projected to be 89,200 (36 098 ha) in 2020. Each acre was estimated to receive an average of 2.04 acre-feet (6 220 cubic metres per hectare--m^3/ha) of irrigation water every year it was under cultivation.

Following the trend evident at the time the study was begun, the annual per capita water demand for domestic use in Ventura County was projected to increase from .188 acre-foot (232 m^3) in 1970 to .239 acre-foot (295 m^3) in 2020.

Although the future demand may prove to be different from these estimates, the conclusions and recommendations coming out of this study would remain the same.

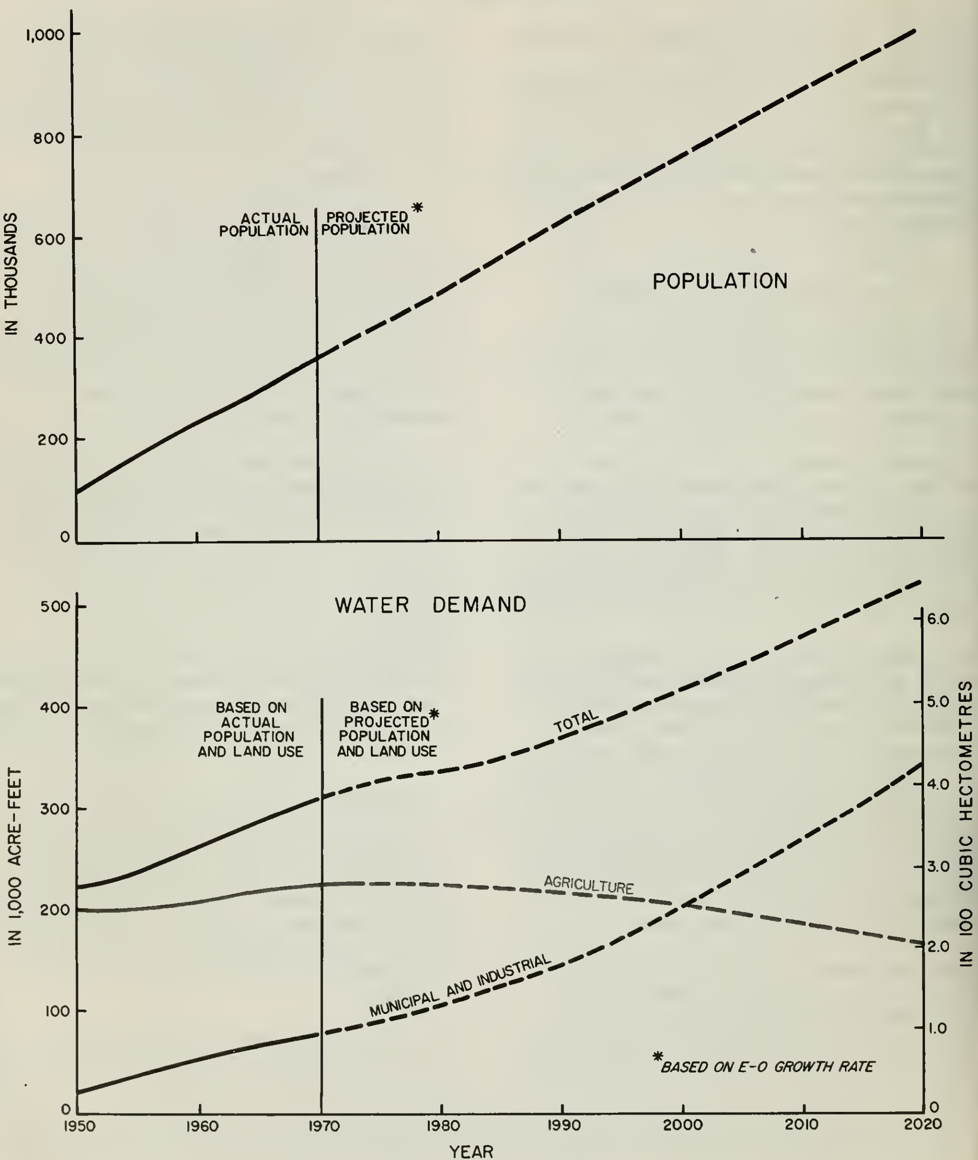
Inventorying Supplies and Facilities

To meet this growing demand, water is available from four sources--surface water, reclaimed water, imported water, and ground water (Table 1 and Figure 6). The existing and proposed transmission and storage facilities are shown in Figure 7.

It should be noted that the ground water basins themselves are important as part

* The E-O population growth rate established by the California Department of Finance in 1971. This growth rate assumes that, on the average, each 1,000 women will bear 2,110 children during their lifetimes (U. S. Census Bureau Fertility Series E) and that the net migration into the State will be zero for each year of the study period. Since this study was started, the Department of Finance has revised the growth rate twice, both times setting an even smaller rate.

Figure 5 - PROJECTED POPULATION AND WATER DEMAND IN VENTURA COUNTY



of the network of storage and delivery facilities. To illustrate, the deep percolation and subsurface inflow into a ground water basin are comparable to the inflow into a surface reservoir, the transmissive characteristics of the aquifers to the delivery characteristics of a surface delivery system, and the piezometric pressure and ground water table to the hydraulic grade line in a surface distribution system.

And, of course, underground systems, as well as those above ground, are capable of storing water for later use.

Table I
WATER SUPPLY USED IN VENTURA COUNTY IN 1970

Source	Amount In acre-feet	Amount In cubic hectometres	Percent of total
Ground water	260,000	320	83
Imported water	32,000	39	10
Diverted surface water	18,000	23	6
Reclaimed water	4,000	5	1
Total	314,000	387	100

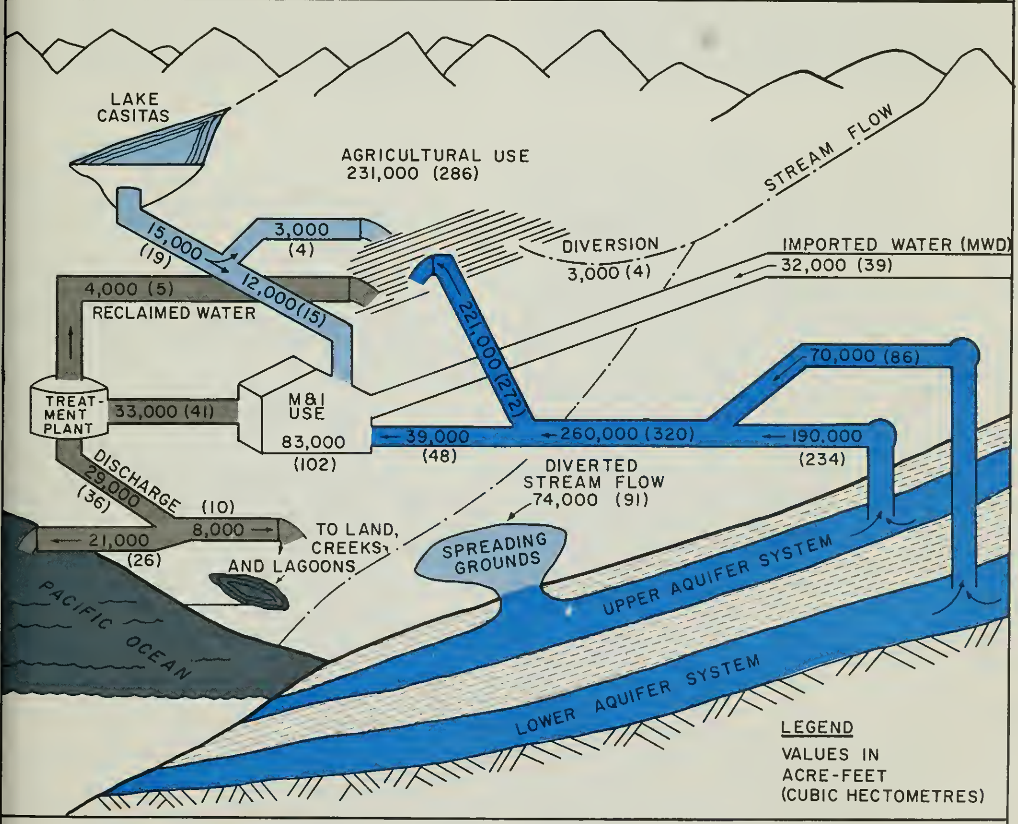


Figure 6 - WATER SUPPLY USED IN VENTURA COUNTY IN 1970

Surface Water

The amount of local surface water available in Ventura County is determined by the amount of rainfall. In assigning a value to the rainfall for 1975-2020, the average annual amount -- 17.5 inches (444 millimetres) -- that fell in 1934-64 was used.[18,19]

The investigators used this value even though they recognized that, under actual conditions, the amount of rainfall would experience cyclic fluctuations. From previous studies, they had found that imposing the fluctuations on the study would not affect the overall findings and conclusions; therefore, the additional time and expense required were not considered justified.

Quality of the surface water throughout the county (as measured in concentration of total dissolved solids--TDS) has ranged from 100 to 4 100 milligrams per litre (mg/l), with most of the water during periods of high flow suitable for all beneficial uses.[34]

The amount of local surface water used in the past was found to constitute the maximum that could be conserved with existing facilities.[23,24] As Figure 7 indicates, two projects have been proposed for diversion of Sespe Creek water, but neither has been approved for construction.[11,13] Therefore, the management alternatives considered in this study did not include a variation in the amount of surface water used.

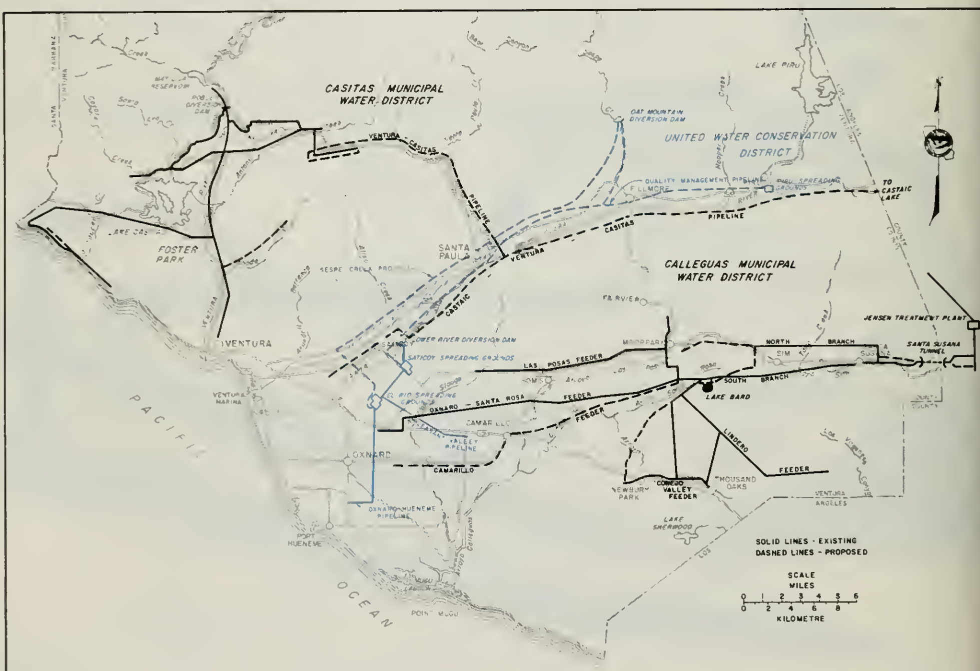


Figure 7 - EXISTING AND PROPOSED TRANSMISSION AND STORAGE FACILITIES

However, if a project to conserve water from Sespe Creek is built, the overall quality of surface water would be improved and the amount of surface runoff to the ocean would be reduced. The additional water thus conserved could be released at the spreading grounds, which would mean that nearby ground water levels would be higher than reported here. On the other hand, this additional surface water could be used directly to meet demand; if so, the amount of imported water required could be reduced by a corresponding amount.

Reclaimed Water

Reclaimed water is now providing a small amount of supply; some treated waste water is being used for irrigation, but most waste water is discharged to streams or cesspools and thus finds its way to the ground water basins or the ocean.[27,34]

How much of this supply will be used in the future is uncertain, because of the policies of regulatory agencies. The State Health Department, to guard against possible health hazards, prevents the use of reclaimed water for direct domestic use and requires expensive treatment for that reclaimed water it permits to be used for replenishment of ground water basins which furnish a domestic supply. If a basin could be dedicated to agricultural use, a large amount of reclaimed water could be spread for replenishment. This would require approval of the State Water Resources

xisting Facilities

asitas Municipal Water District operates Lake asitas, Matilija Reservoir, Robles Diversion am, and Robles Diversion Canal.

nited Water Conservation District operates ake Piru and the Lower River Diversion Dam; iru, Saticoy, and El Rio spreading grounds; a ellfield at the El Rio spreading grounds; the leasant Valley pipeline; and the Oxnard-ueneme pipeline.

alleguas Municipal Water District transports ater imported from The Metropolitan Water istrict of Southern California through the Santa usana Tunnel and the South Branch, North ranch, Lindero feeder, Conejo Valley feeder, as Posas feeder, and Oxnard-Santa Rosa feeder.

roposed Facilities

entura River Extension Project would modify the obles Diversion Dam and enlarge the Robles anal. The project was proposed and evaluated the U. S. Bureau of Reclamation.

espe Creek Project, also planned by the U. S. ureau of Reclamation, would consist of three ams on Sespe Creek (one of which would be an at Mountain diversion dam) and a pipeline to eliver water to Fillmore, Santa Paula, Oxnard, nd the eastern part of Ventura. It could also ovide water for the Oxnard-Hueneme pipeline.

astaic-Ventura-Casitas Pipeline has been onsidered by the Casitas Municipal Water istrict and the City of Ventura. It would eliver 15,000 acre-feet (19 cubic hectometres) per year of State Water Project water to Ventura and, by way of a lateral branch, to Ojai. This project includes consideration of construction of a treatment plant by the Castaic Lake Water Agency.

Quality Management Pipeline and Oat Mountain Diversion Project has been proposed by the United Water Conservation District. It would require construction of a 27-mile (43-kilometre) pipeline from the Piru spreading grounds to the Saticoy and El Rio spreading grounds, an Oat Mountain diversion dam (Fabridam) on Sespe Creek, a 5-mile (8-kilometre) pipeline from the dam to the quality management pipeline, and sediment settling basins downstream from the dam.

To operate the project, 5,820 acre-feet (7 cubic hectometres) per year of water would be released from Pyramid Reservoir to flow down Piru Creek to Lake Piru and then to Piru spreading grounds where it would enter the quality management pipeline. It would be joined at Fillmore by water diverted from Sespe Creek, and the untreated water would then be delivered to the contracting agencies.

Calleguas Municipal Water District plans to add to its distribution system, including an Oxnard feeder.

Importation of State Water Project water is the subject of a feasibility study jointly funded by Casitas Municipal Water District, United Water Conservation District, and the City of Ventura. Purpose of the study is to determine and evaluate several alternatives for importing water by the three agencies.

Photo courtesy Ventura Regional County Sanitation District

LAKE PIRU, near the eastern border of Ventura County, is operated by United Water Conservation District.

Control Board to permit an exception to its policies, which are, in general, wastes discharged to the waters of the State must not degrade the present quality of the receiving water and the quality of ground water must be maintained at a level suitable for all identified beneficial uses.

Because of this uncertainty, the values regarding waste water reclamation used in this study were those given in Water Quality Control Plan Report of Santa Clara River Basin (4A).[7] The recommended water quality control plan projects a total production in year 2000 of 131,240 acre-feet (162 cubic hectometres--hm^3) of waste water in Ventura County, of which, 3,400 acre-feet (4 hm^3) would be reclaimed.*

Therefore, neither the quantity nor quality of reclaimed water was included as a variable in the alternatives considered in this study. Further, the U. S. Bureau of Reclamation is conducting the Ventura County Water Management Project investigation, which includes detailed studies of specific waste water reclamation and reuse projec throughout the county. The recommendati from that study will form a basis for an expanded use of reclaimed water, but the study had not been completed at the time this report was prepared.

Imported Water

Water has been imported into Ventura County since the fall of 1963 when Calleguas Municipal Water District, a member of The Metropolitan Water District of Southern California (MWD), delivered 200 acre-feet (.25 hm^3) of Colorado River water for use in Simi Valley.[9,25] By 1975, the importation ha increased to 48,990 acre-feet (60 hm^3).

Until April 1972 all water imported into Ventura County came from the Colorado River. Since then, importations have been from the State Water Project only, and MWD has indicated they will continue

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* Does not include amounts being reclaimed at Fillmore, Santa Paula, and Rockwell International treatment plants in 1970.

to be from that source. This has meant an improvement in quality: TDS content of State Water Project water in 1974 was less than 300 mg/l, while that from the Colorado River was more than 700 mg/l. Part of the water being imported by Calleguas Municipal Water District has been delivered to the City of Oxnard since July 1965.

As a member of MWD, Calleguas will, during years of abundant supplies to MWD, be able to import as much water as its system can deliver. During years of deficient supplies to MWD, the supply to Calleguas will be based on the ratio of its accumulated payment to the total accumulated payment of all member agencies of MWD.

In addition, the City of Ventura has contracted for 10,000 acre-feet ($12\ hm^3$) per year of State Water Project water, Casitas Municipal Water District for 5,000 acre-feet ($6\ hm^3$) per year, and United Water Conservation District for 5,000 acre-feet ($6\ hm^3$) per year.* No date has been set for these importations to begin, and several alternative transmission and treatment facilities are now being considered.

On the basis of this information, variations in the amount of imported water used--both directly and for artificial recharge of the ground water basins--were among the management alternatives considered in this study. Recognizing that the water agencies in Ventura County may be able to obtain additional water supplies beyond those now available, the investigators tested the effects of using larger amounts. These larger amounts are

* The contract for 20,000 acre-feet ($24\ hm^3$) per year is between Ventura County Flood Control District and the State of California, and it is administered by the Casitas Municipal Water District as a subcontractor.

Photo courtesy United Water Conservation District

SATICOY SPREADING GROUNDS are used to recharge the Oxnard Plain Basin. View is toward the south.

included as imported water in the discussions of the alternatives. (In addition, the injection of imported water to create a "barrier" against further intrusion of sea water into coastal aquifers was one of several methods of control tried in the study.)

Ground Water

A study was made of characteristics of ground water basins and the quality and quantity of the water they contain to determine if the amount of ground water used could be increased and, if so, by how much.[15-17, 28-31]

The water-bearing portions of the two subareas and the major ground water basins are identified in Figure 8. The Santa Clara-Calleguas Subarea was found to contain 29 million acre-feet (36 000 hm^3) of water in storage in 1970, whereas the Ventura River Subarea contained 89,000 acre-feet (110 hm^3).* The Technical Coordinating Committee recommended that primary emphasis be put on management choices for the Santa Clara-Calleguas Subarea.

Beneath the Oxnard Plain, fresh water is contained in five aquifer zones (the Oxnard, Mugu, Hueneme, Fox Canyon, and Grimes Canyon aquifer zones), which are separated by clay layers of low permeability. For the mathematical models these zones were separated into an upper system (Oxnard and Mugu aquifer

* The volumes were determined by multiplying the volume of saturated sediments by the specific yield of each type of sediment. (See reference 31.)

Figure 8 - GROUND WATER BASINS

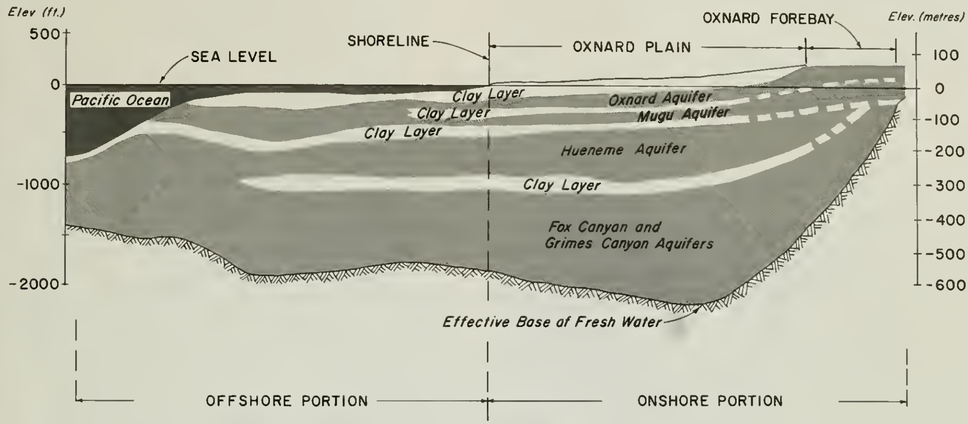


Figure 9 - SCHEMATIC OF GROUND WATER SYSTEMS
OXNARD PLAIN AND VICINITY

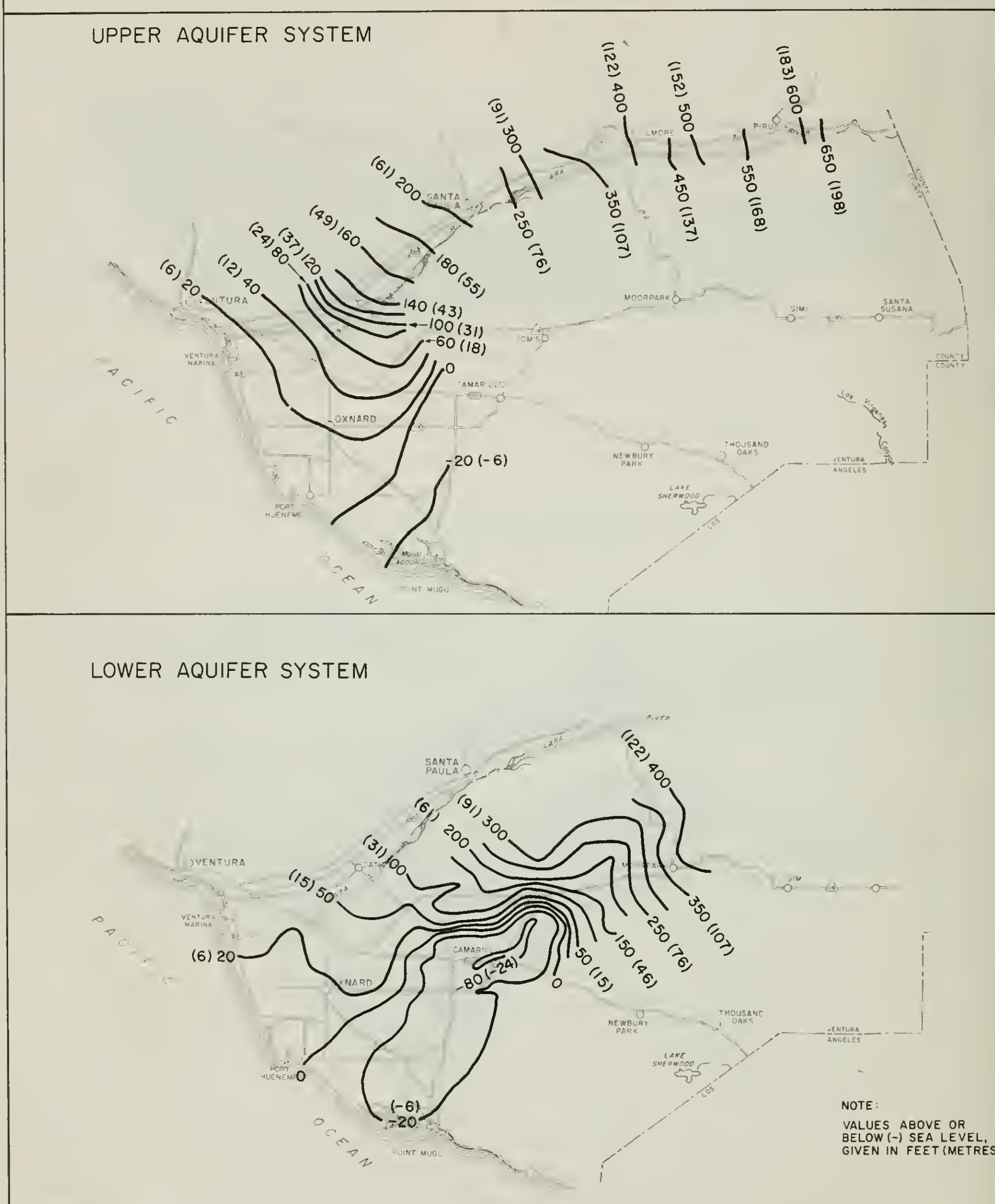
zones) and a lower system (Hueneme, Fox Canyon, and Grimes Canyon aquifer zones). Figure 9 contains a schematic of the aquifer zones, and Figure 10 contains maps showing water levels in both aquifer systems at the start of the study period.

As Figure 9 indicates, the investigators have concluded that the Lower Aquifer System extends several miles offshore. This conclusion is based on an evaluation of logs of oil and water wells and a sounding (sparker) survey conducted by the U. S. Geological Survey, which have shown that (1) fresh water is contained in the Lower Aquifer System at the shoreline, (2) the natural gradient of water in that system is seaward, and (3) the clay layer separating the Upper and Lower Aquifer Systems extends several miles offshore. Estimates are that the offshore extension of this system contains 5 to 8 million acre-feet (6 000 to 10 000 hm^3) of fresh water, of which more than half may be recoverable. This water is recoverable by pumping from the onshore portion of the Lower Aquifer System, which would lower the water levels, thus causing the fresh water in the offshore portion to move inland.

The Upper Aquifer System has been intruded by sea water two to three miles (3 to 5 kilometres--km) inland near Port Hueneme and Point Mugu, as shown in Figure 11. Definite evidence of active intrusion was first found in the 1950s. The rate of movement near Port Hueneme was measured as 500 feet (150 metres--m) per year between 1963 and 1974.

So far, the only probable evidence of sea water that has been found in the Lower Aquifer System is in two wells approximately 2-1/4 to 2-1/2 miles (3.6 to 4 km) north of Point Mugu, which have shown concentrations of chlorides of 306 to 10 400 mg/l (high chloride concentrations are the usual indication of sea water). Possible explanations include: (1) the clay layer between

Figure 10-GROUND WATER LEVELS, 1970



DEPARTMENT WATER RESOURCES, SOUTHERN DIVISION, 1976 aquifer zones is thin in places, thus permitting sea water to seep down from the upper intruded system; (2) some wells are serving as conduits for the sea water from the upper system; and (3) water at these points in the Lower Aquifer System is naturally high in chlorides.

Between the Los Angeles-Ventura County line and the ocean, the Santa Clara River Valley contains four major ground water basins: the Piru, Fillmore, Santa Paula, and Mound Basins (Figure 8). Of these, the Fillmore Basin contains the greatest accumulation of water-bearing materials--fresh water has been found to extend to more than 3,800 feet (1 200 m) below sea level about 1 mile (1.5 km) south of the City of Fillmore.

In all four basins, the water-bearing materials form a single aquifer system. That in the Piru, Fillmore, and Santa Paula Basins is unconfined, but that in the Mound Basin is confined.* These basins are in hydraulic continuity with each other, and the Mound Basin and Santa Paula Basin are in hydraulic continuity with aquifer zones under the Oxnard Plain.

The East and West Las Posas Basins are primarily underlain by the Fox Canyon and the Grimes Canyon aquifer zones. These aquifer zones are confined, but within the basins, shallow, unconfined aquifer zones are found near Fairview and near Moorpark. Natural replenishment of the Fox Canyon and Grimes Canyon aquifer zones takes place

* A "confined" aquifer is overlain by a relatively impermeable clay layer, which retards the movement of water from and to the surface. An "unconfined" aquifer is free of this restriction.

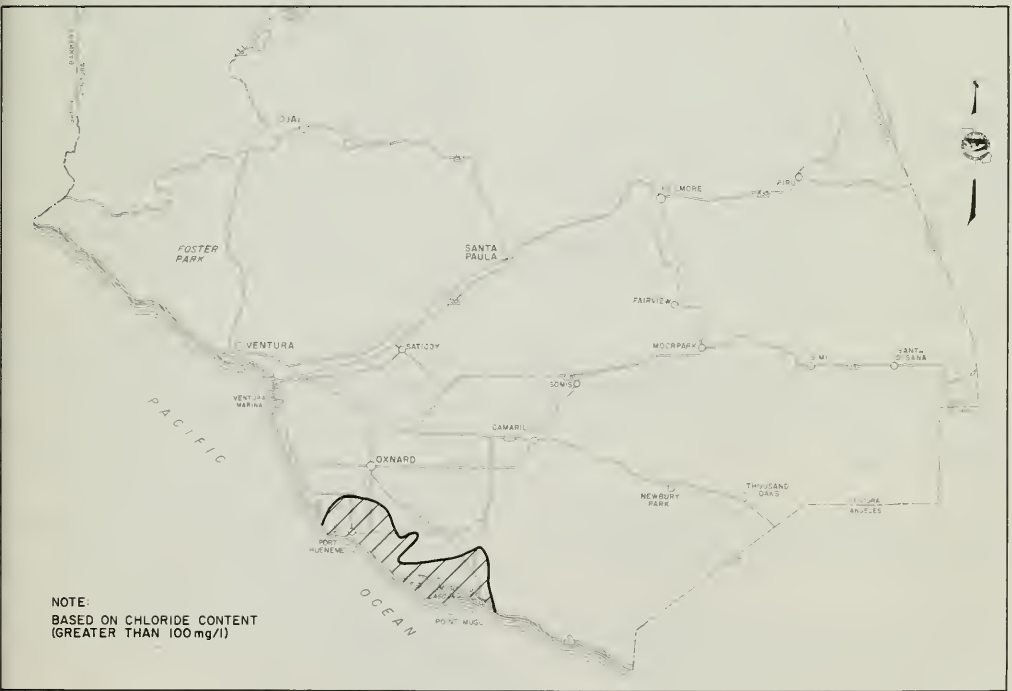


Figure 11-SEA WATER INTRUSION FRONT, 1974

primarily along the south flank of South Mountain where the two aquifer zones are exposed; however, no spreading grounds have been developed there. Water levels are declining by 4 to 5 feet (1.2 to 1.5 m) a year, indicating that the amount of extraction is exceeding the amount of replenishment.

The Pleasant Valley Basin has been intensively folded and faulted; these folded and faulted features serve to separate it from the basins to the north and east. It is differentiated from the Oxnard Plain Basin on the west by the absence of the Oxnard and Mugu aquifer zones.

In the Pleasant Valley Basin also, the Fox Canyon and Grimes Canyon aquifer zones are the major water producers. These form a single confined system in hydraulic continuity with the Lower Aquifer System of the Oxnard Plain. By 1970, a pumping depression had appeared north of Camarillo, which indicates that extractions were exceeding replenishment at that point. The water-bearing portion of the Simi Valley contains water of inferior quality, and that in the Conejo area is small. Therefore, in this study neither was considered in the alternative management measures so that adequate time would be available for consideration of other significant factors.

In 1970, approximately 260,000 acre-feet (320 hm^3) of ground water was pumped in the Santa Clara-Calleguas Subarea. Of this, 75 percent came from the Upper Aquifer System.

Figure 12 shows the average TDS content of water extracted from each of the aquifer systems at the start of the study period.[34]

In 1970 the Santa Clara-Calleguas ground water basins were replenished with approximately 194,000 acre-feet (239 hm^3) of local water (from percolation of streamflow, rainfall, and irrigation water) and waste water. Thus, the amount pumped that year was exceeding the replenishment by about 66,000 acre-feet (81 hm^3).

In the Oxnard Plain, lowered water levels recover during wet seasons as a result of a reduction in pumping. However, the period of reduced pumping is usually too short to push back the sea water intrusion front for more than a short distance, and when full pumping resumes, the front moves inland again.

The El Rio and Saticoy spreading grounds in the Oxnard Forebay are the primary recharge areas for both the Upper and Lower Aquifer Systems under the Oxnard Plain (Figure 7). However, the shallowness of the sediments and the flatness of the water level gradients tend to slow the movement of spread water outward through the aquifer zones. Under current conditions, an average of 46,400 acre-feet (57 hm^3) annually is being captured and spread at these two facilities.* In 1970 the total was 62,300 acre-feet (77 hm^3). More water can be captured and spread at these two spreading grounds if proposed construction (including Oat Mountain Diversion project and an improved Saticoy diversion) is carried out.

In addition, the Piru spreading grounds is near the confluence of Piru Creek and the Santa Clara River. The Piru Basin is being replenished with an average of 8,000 acre-feet (10 hm^3) per year through this recharge area. In 1970 the total recharge was 11,500 acre-feet (14 hm^3). With the information developed, the investigators concluded that the amount of ground water pumped, the pumping pattern used, and the amount of recharge water spread could be changed. Therefore, variations in these elements were included in the management alternatives studied.

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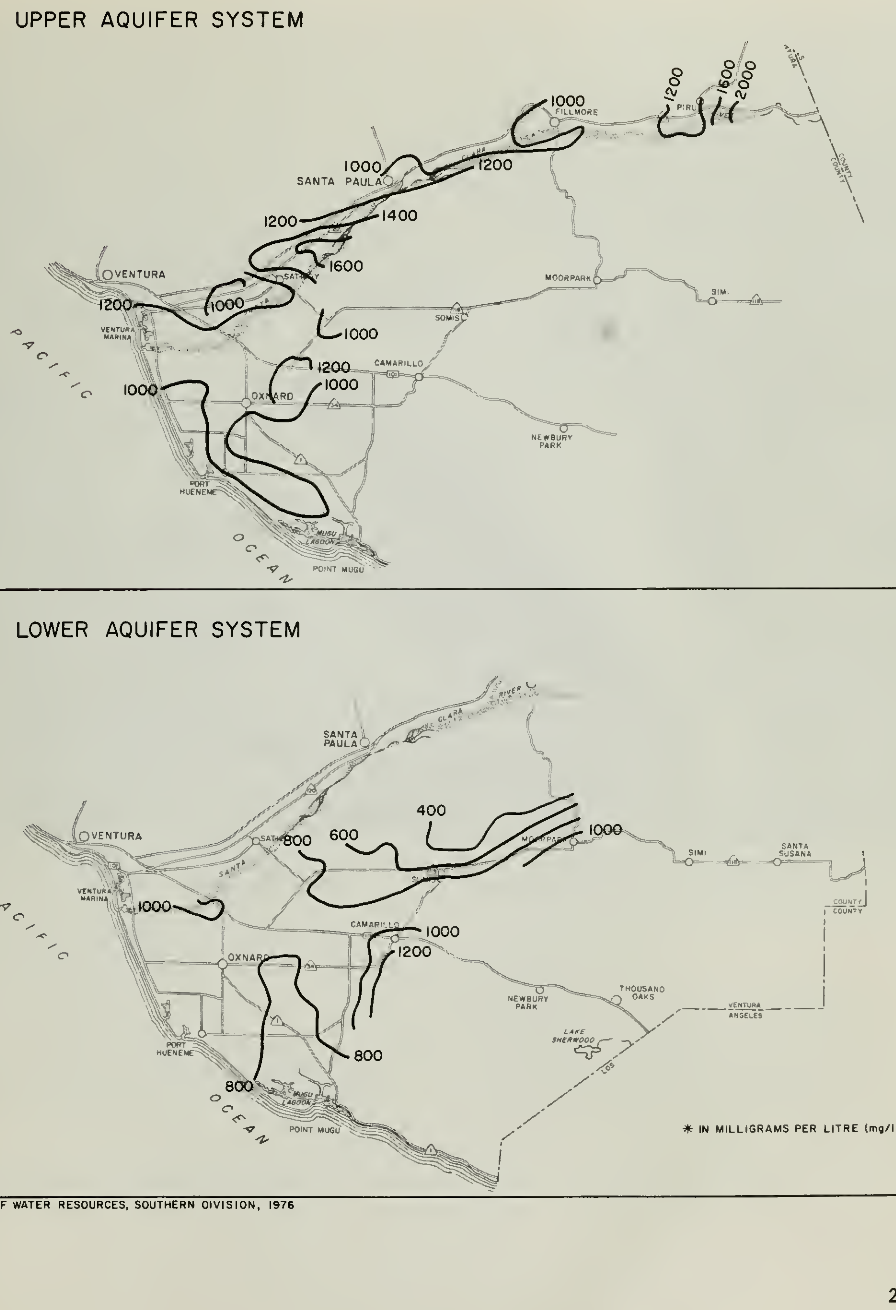
*Includes 39,400 acre-feet (49 hm^3) spread plus 7,000 acre-feet (8 hm^3) delivered to Pleasant Valley for irrigation. It should be noted that before these spreading grounds were developed, most of this water flowed to the ocean.

Figure 12-TOTAL DISSOLVED SOLIDS CONTENT*
OF EXTRACTED GROUND WATER, 1970



* IN MILLIGRAMS PER LITRE (mg/l)

DEPARTMENT OF WATER RESOURCES, SOUTHERN OIVISION, 1976

SANTA CLARA RIVER VALLEY showing citrus groves along the river banks. The view is from Piru looking toward the west. South Mountain is on the left and the foothills of the Topatopa Mountains on the right.

III. ANALYSIS OF MANAGEMENT ALTERNATIVES

Using the basic information obtained in the inventory, the investigators determined that several management alternatives were open to Ventura County. With the help of the Technical Coordinating Committee, a selection was made of alternatives to study in detail. The study was designed to show (1) the physical reactions of the ground water basins; (2) relative costs; and (3) secondary effects of operation of each alternative selected. From the results thus obtained, the most economical, practical, and environmentally acceptable features of the management alternatives could be identified for use by local water leaders in developing their future course of action.

Alternatives Selected for Analysis

All the management alternatives that were given serious consideration involved variations in:

- o Amount of ground water pumped* and pumping pattern used
- o Amount of water imported for both direct use* and artificial recharge

Variations in these components were combined in a number of management alternatives, each of which would furnish sufficient water to meet the projected annual demand. (No consideration was given to monthly, daily, or hourly demand.)

As has been pointed out, the size of both the actual demand and supplies could be different from what have been projected in this report. In either case, only the quantities assigned to the components would have to be changed. For example, any increase in local supplies would be reflected in a decrease in the amount of water imported. An increase in local supplies might take place if a proposed project on Sespe Creek were built, thus increasing the amount of surface water captured for use; if the regulations governing disposal of treated water were changed to permit an increase in its use; or if conjunctive operation of more ground water basins with surface water conservation facilities were instituted (such as that now being considered in the Ventura River Subarea).

From the many alternatives devised, five were selected for detailed study. These are presented in Table 2. Briefly, the variations are:

A. Maximum Extraction and Recharge = Use as much ground water as possible and recharge in the existing spreading grounds with large amounts of imported water.**

B. Maximum Extraction = Use as much ground water as possible with no additional recharging.

C. No Change in Storage = Use approximately as much ground water as is returning to the basins and directly use large amounts of imported water.

D. Maximum Extraction and Recharge and Changed Pumping Pattern = Use as much ground water as possible, shift pumping away from coastal upper aquifers, and recharge with large amounts of imported water.**

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*Projected demand determined the variations used.

**The amount selected for recharge was based on a trial and error analysis using the mathematical model and on a study of the spreading grounds.

Table 2

FIVE MANAGEMENT ALTERNATIVES* SELECTED FOR ANALYSIS

Source of Supply	1970-2020 Annual average amount In acre-feet	In cubic hectometres
**** A: MAXIMUM EXTRACTION AND RECHARGE**		
Surface water	20,000	25
Reclaimed water	3,400	4
Imported water		
1. *Direct use* amount required to meet demand that cannot be met with other supplies	11,000	14
2. *Artificial recharge* with a maximum of 100,000 acre-feet (123 cubic hectometres) per year of water of quality of that of State Water Project	77,000	95
Ground water		
1. Use to meet as much of demand as possible	311,000	384
2. Use same pumping pattern as in 1967		
**** B: MAXIMUM EXTRACTION**		
Surface water	20,000	25
Reclaimed water	3,400	4
Imported water		
1. *Direct use* amount required to meet demand that cannot be met with other supplies	11,000	14
2. *Artificial recharge* none	0	0
Ground water		
1. Use to meet as much of demand as possible	311,000	384
2. Use same pumping pattern as in 1967		
C: NO CHANGE IN STORAGE		
Surface water	20,000	25
Reclaimed water	3,400	4
Imported water		
1. *Direct use* amount required to meet demand that cannot be met with other supplies	143,000	176
2. *Artificial recharge* none	0	0
Ground water		
1. Attempt to limit to amount being replenished	179,000	221
2. Use same pumping pattern as in 1967		

Source of Supply	1970-2020 Annual average amount In acre-feet	In cubic hectometres
D: MAXIMUM EXTRACTION AND RECHARGE AND CHANGED PUMPING PATTERN		
Surface water	20,000	25
Reclaimed water	3,400	4
Imported water		
1. *Direct use* amount required to meet demand that cannot be met with other supplies	11,000	14
2. *Artificial recharge* with a maximum of 100,000 acre-feet (123 cubic hectometres) per year of water of quality of that from State Water Project and enlarge size of spreading grounds	77,000	95
Ground water		
1. Use to meet as much of demand as possible	311,000	384
2. Move wells inland and shift pumping to deeper aquifer system		
**** E: SELECTIVE USE OF WATER**		
Surface water	20,000	25
Reclaimed water	3,400	4
Imported water		
1. *Direct use* to meet all municipal demand beyond that being met with diverted surface water	112,000	138
2. *Artificial recharge* none	0	0
Ground water		
1. Use to meet all agricultural demand beyond that being met with diverted surface water	209,000	258
2. Use same pumping pattern as in 1967		

* *Note that alternatives apply only to Oxnard Plain, Santa Clara River Valley, Pleasant Valley, and East and West Las Posas areas.*

** *This alternative was later modified to include drilling of a series of wells for injecting imported water to check intrusion of sea water into aquifers.*

E. Selective Use of Water = Use ground water to meet agricultural demand and imported water to meet municipal and industrial demand.

Clearly, these variations would be reflected in the future quantity and quality of water in the ground water basins and in the extent of facilities required for storing and delivering imported water.

Primary Effects of Alternatives

The physical impacts of operation of each of the management alternatives upon the ground water basins of the Santa Clara-Calleguas Subarea, as determined from operation of mathematical models of the basins, are summarized in Table 3. Each is discussed below.

Sea Water Intrusion

Of concern in Ventura County has been the possible control of the intrusion of sea water into the Upper Aquifer System under the Oxnard Plain (Figure 11).[4] Each of the management alternatives was studied to determine what effect its operation would have on this intrusion.

Under alternative C (No Change in Storage) further intrusion would be stopped in the Upper Aquifer System by 1978. By 2020 the aquifer zones would be losing fresh water to the ocean as subsurface outflow.

Intrusion would be stopped in 1990 under D (Maximum Extraction and Recharge and Changed Pumping Pattern), which would combine a large recharge of imported water with (1) an increase in the size of the spreading grounds in Oxnard Forebay, (2) a reduction in the amount of pumping from wells along the coast, and (3) a shift of pumping from the Upper Aquifer System to the Lower Aquifer System.

However, the recharge of a large amount of imported water plus the pumping of a large amount of ground water, as done in alternative A (Maximum Extraction and Recharge), would not push back the intrusion front to the coast by 2020, because of the limited transmissivity of sediments and the flat water level gradients. Likewise, with alternative B (Maximum Extraction) and alternative E (Selective Use of Water), the intrusion front would not be reversed by 2020.

Therefore, these three management alternatives were modified to include installation of a "barrier" to control the intrusion. The barrier would consist of a series of injection wells along the coast through which imported water could be forced into the aquifer system to build up the water level to repel the intruding sea water.*

With operation of the barrier, further intrusion would be stopped in 1982 for E (Selective Use of Water), in 1983 for A (Maximum Extraction and Recharge), and in 1986 for B (Maximum Extraction).

Water Lost to Ocean

Because of the low elevation of the ground surface in the Oxnard Plain and geologic conditions, percolating water tends to build up and appear as rising water in the stream channels and drainage ditches, which flow into the ocean.[32]

Therefore, operation of each of the management alternatives was studied to determine how much might be lost this way. The losses through rising water would average from 9,000 acre-feet (11 hm^3) for alternative B to 27,000 acre-feet (33 hm^3) per year for alternatives A and E during the period 1970-2020. By 2020 the amounts being lost each year through rising water would range from none for alternative B to 33,000 acre-feet (41 hm^3) for alternative E.

*One of several different methods that might be used to control the intrusion.

Table 3
PHYSICAL IMPACTS OF OPERATION OF FIVE MANAGEMENT ALTERNATIVES

Item	Alternative* A	B	C	D	E
In acre-feet					
Sea water intrusion					
Without barrier, annual intrusion in 2020	16,000	40,000	0	0	6,000
For barrier, injection of fresh water, average annual, 1970-2020	10,000	17,000	0	0	6,000
Rising water to ocean					
In 2020	22,000	0	6,000	14,000	33,000
Average annual, 1970-2020	27,000	9,000	15,000	21,000	27,000
Change in storage, 1970-2020					
Onshore aquifers	-1,056,000	-2,185,000	-162,000	-1,152,000	-619,000
Offshore aquifers**	-1,095,000	-1,800,000	+390,000	-830,000	-610,000
In cubic hectometres					
Sea water intrusion					
Without barrier, annual intrusion in 2020	20	49	0	0	7
For barrier, injection of fresh water average annual, 1970-2020	12	21	0	0	7
Rising water to ocean					
In 2020	27	0	7	17	41
Average annual, 1970-2020	33	11	18	26	33
Change in storage, 1970-2020					
Onshore aquifers	-1 303	-2 695	-200	-1 421	-763
Offshore aquifers**	-1 351	-2 200	+481	-1 024	-752
Pumping lift, 2020					
In feet	200	300	100	250	200
In metres	61	91	30	76	61
Average TDS in mg/l					
In 1975					
Applied water for municipal and industrial	1 080	1 040	590	980	350
Applied water for agriculture	1 060	1 060	980	1 060	1 050
Pumped water	1 070	1 070	1 060	1 060	1 060
In 2000					
Applied water for municipal and industrial	1 060	1 240	510	970	350
Applied water for agriculture	1 040	1 200	820	990	1 110
Pumped water	1 070	1 240	1 040	1 010	1 110
In 2020					
Applied water for municipal and industrial	1 090	1 460	530	950	350
Applied water for agriculture	1 110	1 330	940	1 020	1 120
Pumped water	1 140	1 420	1 070	1 050	1 120

* Key to alternatives: A. Maximum Extraction and Recharge; B. Maximum Extraction; C. No Change in Storage; D. Maximum Extraction and Recharge and Changed Pumping Pattern; E. Selective Use of Water. (Note that alternatives apply only to Oxnard Plain, Santa Clara River Valley, Pleasant Valley, and East and West Las Posas.)

** Represents total flow seaward (+) or landward (—) at shoreline. The values given were established by computing the subsurface inflow from the offshore aquifers containing fresh water.

This water could be conserved by collecting and conveying it to the El Rio and Saticoy spreading grounds. The decision on whether or not to follow this practice would depend on several factors, among which are quality of the rising water and cost of pumping the water inland to the spreading grounds.

Also, the amount of extraction and the pumping pattern used could be adjusted to minimize or eliminate the loss.

Alternative D (Maximum Extraction and Recharge and Changed Pumping Pattern) and alternative C (No Change in Storage) would not only experience rising water, but would also lose water to the ocean through subsurface flow. Alternative D would be losing an annual average of 1,000 acre-feet (1.2 hm^3) and C (No Change in Storage) would be losing an annual average of 12,000 acre-feet (15 hm^3) as subsurface flow from the Upper Aquifer System.

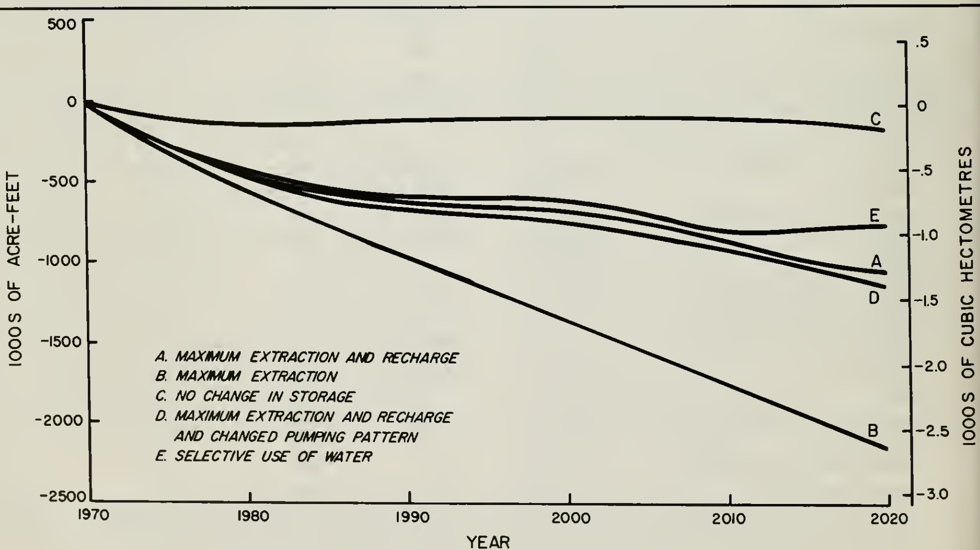
Change in Storage

Under operation of all the management alternatives, the onshore ground water basins will contain less water in 2020 than they did in 1970, given the set of circumstances used in this study.[31]

This decrease ranges from 162,000 acre-feet (200 hm^3) for alternative C to 2,185,000 acre-feet (2 695 hm^3) for alternative B as shown in Table 3 and on Figure 13.

These decreases do not include the expected change in fresh water storage in the offshore portion of the Lower Aquifer System, which may range from 610,000 acre-feet (752 hm^3) less for alternative E to 1,800,000 acre-feet (2 200 hm^3) less for alternative B, except in the case of C (No Change in Storage), which would show a 390,000-acre-foot (481 hm^3) increase. Obviously if a substantial amount of water is pumped from the Lower Aquifer System,

Figure 13-ACCUMULATED DECREASE IN STORAGE OF WATER IN ONSHORE AQUIFERS



the fresh water in the offshore portion will move inland.

Pumping Lift

Because of increasing energy costs, one of the key factors in the cost analysis of the management alternatives is the height that ground water must be pumped. The height of ground water levels and the extent of use of deeper aquifers will decide the pumping lifts required.

In Table 3, the lifts of all wells that would be used in each alternative have been averaged. As this indicates, the average pumping lift by the year 2020 would range from 100 feet (30 m) for alternative C to 300 feet (91 m) for alternative B. Figures 14 and 15 show water levels in year 2020 under alternatives B and C.

Quality of Water

TDS content of pumped water was used as the indicator of water quality in the mathematical model of the two aquifer systems underlying the Oxnard Plain.[6,34]

Table 3 shows the average TDS content in 2020 of the applied water used for agriculture and for municipal and industrial purposes. (The assumption had been made that, in general, no imported water would be used for agriculture.)

For agriculture, the TDS content ranges from 940 mg/l for alternative C to 1 330 mg/l for alternative B, and for municipal and industrial purposes, from 350 mg/l for alternative E to 1 460 mg/l for alternative B. Thus the quality of the water used for agriculture would be similar to that which has been used in the past for agriculture in Ventura County. The average TDS content of much of the water for agriculture (including citrus, subtropical, and truck crops) has ranged from 690 to 1 310 mg/l.*

Operation of the quality model also revealed that, among the management alternatives, the one that used the most ground water without spreading imported water (B: Maximum Extraction) resulted in the greatest buildup of TDS in the water extracted from the Upper Aquifer System (Figure 16). In general, as more ground water is pumped from the Upper Aquifer System, the higher will be the TDS content. This is because the used water, which contains salts both naturally and from use, is returned to an ever smaller amount of ground water, thus increasing the concentration.

Comparison of Costs of Alternatives

Once the physical reactions to operation of the management alternatives had been determined, a cost could be assigned to the operation of each and the costs compared (Table 4). Because some of the components, such as amounts of surface water and reclaimed water available, were considered identical under all management alternatives studied, their costs would be common to all. Therefore, in comparing the costs of the alternatives, only those components that would vary have been evaluated. These are:

1. Cost of pumping ground water (includes cost of installing required wells plus the energy to lift the water).

2. Cost of installing and operating a barrier to control sea water intrusion.

3. Cost of imported water required for direct use and for artificial recharge

*As farmers have demonstrated, crop production can be maintained with water of high TDS content if larger amounts of water are applied to leach the salts out of the root zone, provided subsurface drainage is adequate. If subsurface drainage is poor, a drainage system may have to be installed. This would add to the cost, as would the additional amounts of water—how much the cost would be increased would depend upon the specific location. Also, production can be maintained if water of a lower TDS content is mixed with that of high TDS content and the mixture applied to crops.

Figure 14 - ALTERNATIVE B, GROUND WATER LEVELS, 2020

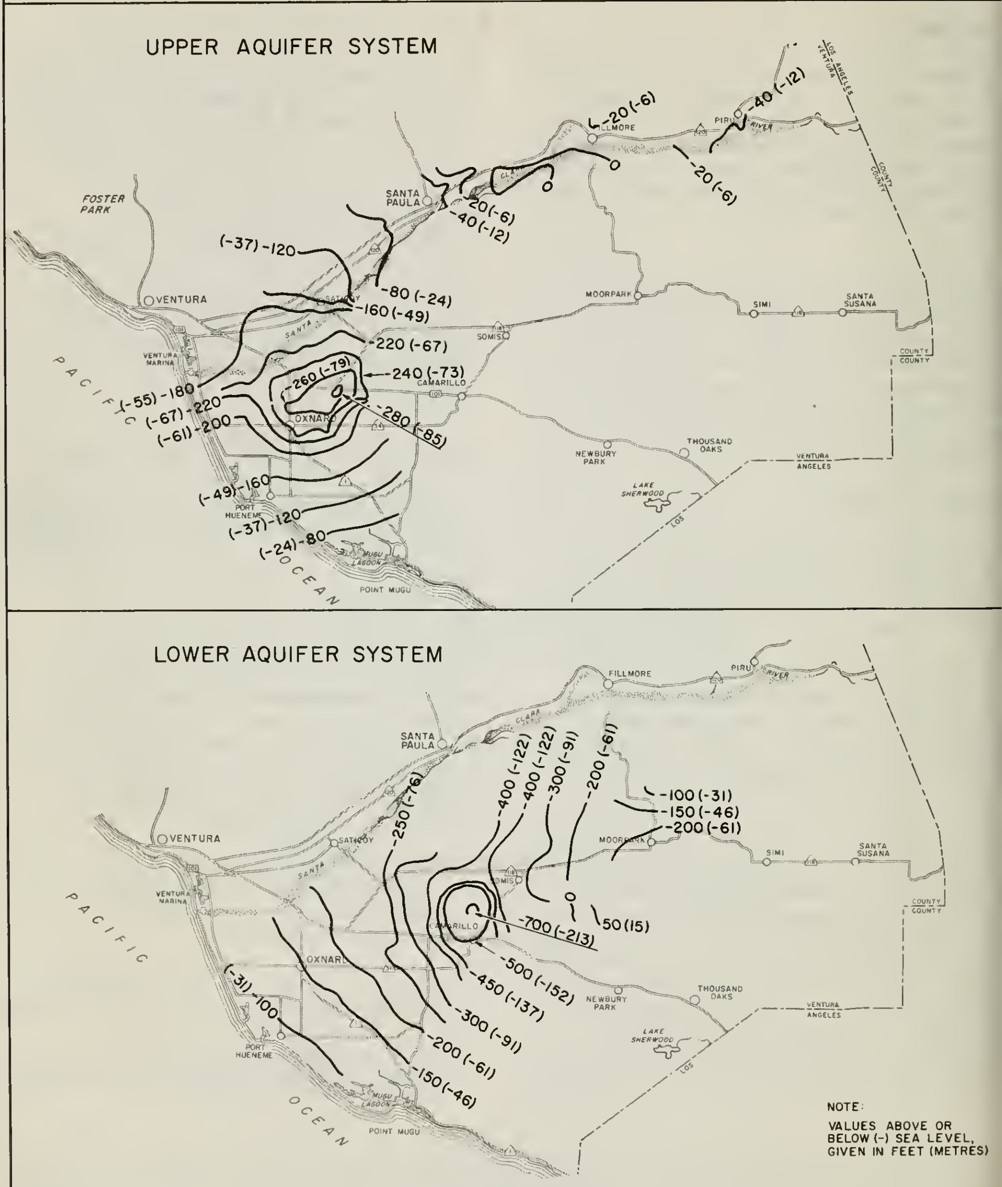


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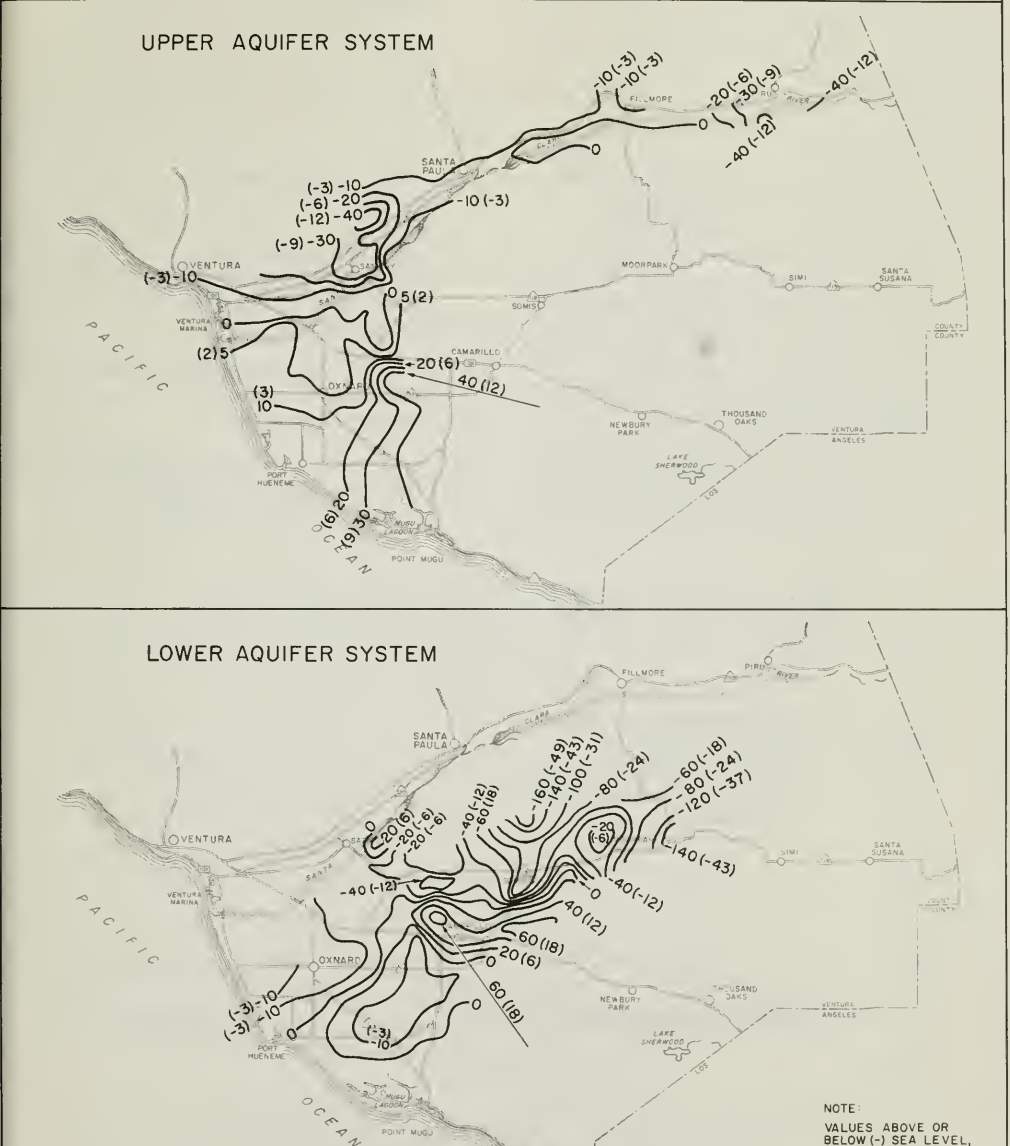
Figure 15 - ALTERNATIVE C, GROUND WATER LEVELS, 2020



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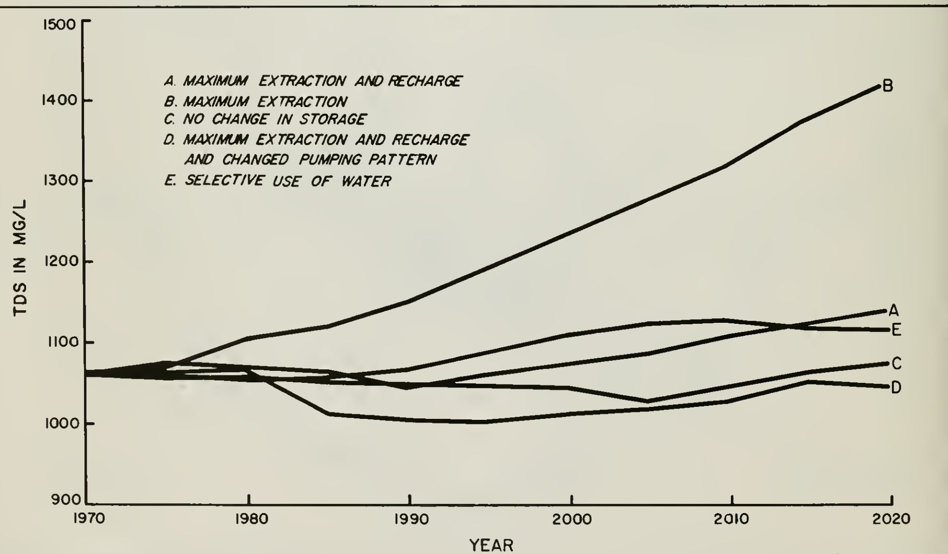
of the ground water basins (includes all the costs of bringing the water into the study area). A cost of $85 per acre-foot (1 233 m^3) was assigned to the 20,000 acre-feet (25 hm^3) of State Water Project water to which entitlements are held in Ventura County. The cost includes (a) the variable operation, maintenance, power, and replacement component of the transportation charge (but not the fixed portion) of State Water Project water, (b) the cost of a pipeline from Castaic Lake to a distribution point near the Saticoy spreading grounds, and (c) the cost of treatment and maintenance. The fixed portion comprises the capital cost component and the minimum operation, maintenance, power, and replacement component of the transportation charge plus the Delta water charge. Because Ventura County will have to pay the fixed portion regardless of what management plan it implements, the fixed portion would not affect the comparison; therefore it was not included in the computations.

All imported water other than that from the State Water Project to which Ventura County holds entitlements was assigned a cost of $100 per acre-foot (1 233 m^3) if it is to be used for municipal and industrial purposes and $75 per acre-foot (1 233 m^3) if it is to be used for spreading or for agriculture. These costs reflect the pricing policy of MWD at the time the study was conducted.

4. Cost of enlarging the spreading grounds to handle an increased amount of imported water.

5. Cost of additional pipelines required to transport imported and ground water to areas of use.

Figure 16 - TDS CONTENT OF PUMPED GROUND WATER



*6. Cost resulting from loss of agricultural production because of the use of water of a high TDS content (called "penalty" cost).[14,33] Unless additional water is applied, production has been found to suffer as the TDS level exceeds the tolerance level of a crop, which varies with different crops. (For example,

*Required a determination of the approximate mix of waters that can be expected to be used in specific portions of the study area.

Table 4

COMPARISON OF COSTS OF MANAGEMENT ALTERNATIVES

Item	Alternative [1] A	B	C	D	E
<u>Present worth, in millions of dollars</u>					
Ground water pumping cost	$69.4	$84.2	$21.9	$68.8	$45.0
Sea water barrier cost					
Facilities	7.5	8.5	0	0	6.6
Water [2]	16.0	25.3	0	0	9.1
Imported water cost					
Municipal and industrial use [3]	10.5	10.5	98.0	10.5	134.1
Agricultural use [2]	0	0	71.3	0	0
Artificial recharge [2]	73.5	0	0	73.5	0
Spreading basin cost	0	0	0	3.9	0
Pipeline cost	0	0	0.7	1.9	0
TOTAL VARIABLE ITEMS	$176.9	$128.5	$191.9	$158.6	$194.8
Penalty costs					
Agriculture (Base: C)	116.1	151.8	0	93.6	121.6
Municipal and industrial (Base: E)	109.0	123.5	30.3	92.8	0
VARIABLE ITEMS + PENALTY COSTS	$402.0	$403.8	$222.2	$345.0	$316.4
Value of ground water in storage (for amount above that in B) [4]	$19.1	0	$52.3	$17.2	$22.6
VARIABLE ITEMS + PENALTY COSTS – VALUE OF GROUND WATER IN STORAGE	$382.9	$403.8	$169.9	$327.8	$293.8
<u>Average annual cost per household[5] in dollars</u>					
Variable items	$60	$42	$64	$54	$65
Penalty costs	133	145	65	107	88
VARIABLE ITEMS + PENALTY COSTS	$193	$187	$129	$161	$153

1. Key to alternatives: A. Maximum Extraction and Recharge; B. Maximum Extraction; C. No Change in Storage; D. Maximum Extraction and Recharge and Changed Pumping Pattern; E. Selective Use of Water. (Note that alternatives apply only to Oxnard Plain, Santa Clara River Valley, Pleasant Valley, and East and West Las Posas.)
2. Using water costing $75 per acre-foot (1 233.5m^3)
3. Only alternatives C and E use large amounts of State Water Project water.
4. Does not include water in offshore aquifers.
5. Based on population projections at 3.23 persons per household.

OXNARD PLAIN, with the U. S. Naval Construction Battalion Center at Port Hueneme in the foreground and the City of Oxnard beyond it. The view is toward the northeast.

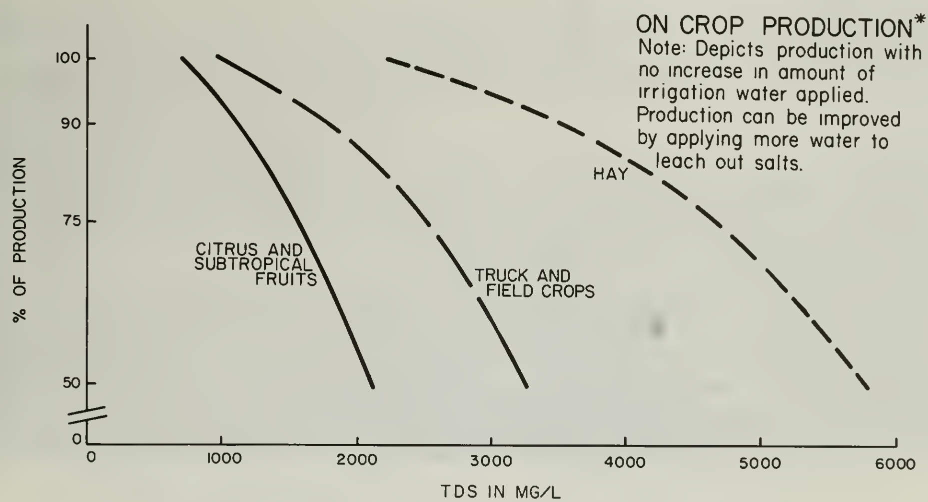
640 mg/l has been found to be the tolerance level for beans, but 4 300 mg/l for sugar beets.) Figure 17 summarizes the relationship between TDS content of water and production of three broad categories of crops grown in the study area.

Because Ventura County is, and is expected to remain, an important agricultural producer, even a 10 percent decline in production of a major crop is significant. In computing values for the penalty cost, as shown in Table 4, the assumption was made that the same amount of irrigation water would be used under all alternatives, regardless of the TDS content; therefore, the management alternative that used the best quality water for agriculture (C: No Change in Storage) served as the base. All others were shown in relation to this. In actual practice, farmers in the study area have been using additional water to maintain production. This concept would modify the penalty cost shown on Table 4, but the alternatives were not evaluated because of the extremely large number of options that would have to be computed.

*7. Added cost burden on the municipal and industrial users of water because they are supplied with water of high TDS content (Figure 17).[10,33] In general, as the TDS content increases, the hardness also increases. Because of this increase in hardness, the householder finds he must use more soap, replace water pipes and heater more often, and buy extra services such as water softeners and bottled water; a value was assigned to this "penalty" cost. The cost vs. TDS relationship depends on particular circumstances involving measures taken to overcome the detrimental effects. Many studies are being conducted to develop credible relationships; among these is a cooperative study, Economic

*Required a determination of the approximate mix of waters that can be expected to be used in specific portions of the study area.

Figure 17 - EFFECTS OF RISING TDS CONTENT OF WATER



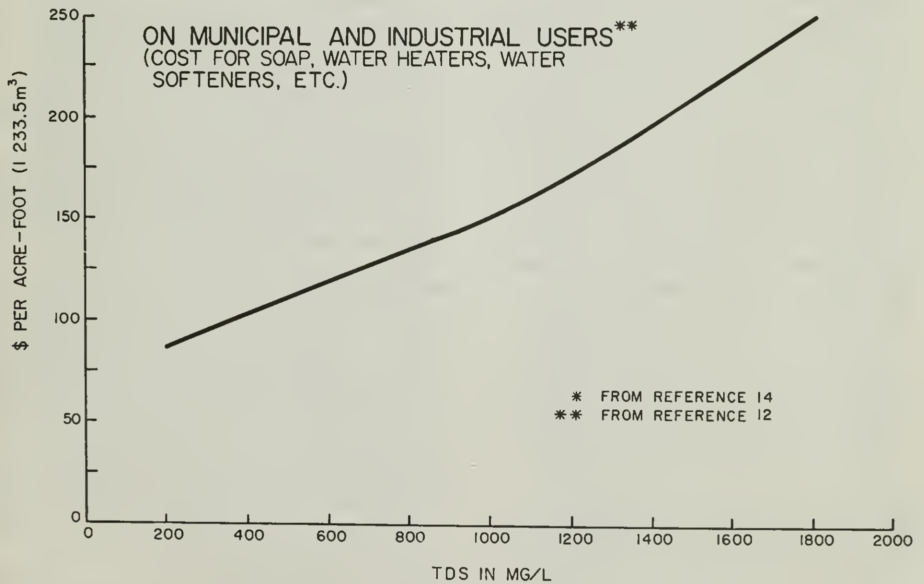


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Photo courtesy United Water Conservation District

CITRUS FRUIT is a major crop in the Santa Clara River Valley of Ventura County.

Consequences of Water Quality Variations on Water Users, now being conducted by the Department of Water Resources and the California Association of Reclamation Entities (WATERCARE). However, for the study reported here, the relationship shown in Figure 17 was used in the absence of a better one. Just as the evaluation of the penalty cost for agriculture requires further development of a low-cost evaluation procedure, so the municipal and industrial penalty cost requires more realistic data. The values assigned in Table 4 are relative to the alternative using the best quality water for municipal and industrial purposes (E: Selective Use of Water).

Because some of the costs will be incurred at different times under the different alternatives, the economic effect of incurring the same total cost will vary. To establish a usable cost comparison of the alternatives, therefore, all costs were converted to the common denominator of present worth. Present worth of the total cost of water service under each alternative may be considered the amount of money that is needed today to meet the future financial obligations associated with that service. The present worths (at 5 percent interest) of the variable components and penalty costs associated with each of the five alternatives are compared in Table 4.

Another way of comparing the costs is to calculate what the average annual cost of that water service will be to each family (household) in Ventura County. This information is also given in Table 4. For this also, only the variable component and penalty costs were evaluated.

In assessing the costs of each alternative the amount of ground water still in storag in 2020 may be considered an asset item.

This amount, which will vary with operatic of the alternatives, will be the smallest with B (Maximum Extraction). For comparison in Table 4, a value, which incorporates the cost of pumping the water, was placed on each acre-foot (1 233 m^3) in storage more than that which would be in storage under B.

In comparing the costs of the alternatives, note that the penalty costs are as large as the variable costs. When better information for computing penalty costs becomes available, the penalty cost for each alternative may change substantially and thus affect the combined variable and penalty costs.

Secondary Effects of Alternatives

Each management alternative studied will have some secondary effects, which will be felt in the immediate area or, as in the case of energy demand, in an outside area. The impacts that will be felt in varying degrees under all or part of the management alternatives are:

- Some water from the ground water basins would appear in the channel of the Santa Clara River, although the amount would vary, as indicated in Table 3. With alternatives A (Maximum Extraction and Recharge), D (Maximum Extraction and Recharge and Changed Pumping Pattern), and E (Selective Use of Water), this flow in the channel could be sufficient to reestablish an estuary at the shoreline and perhaps provide a habitat for fish and other wildlife.

- The landscape would undergo a certain amount of temporary disruption for the construction of wells (whether for a sea water intrusion barrier or for changing the pumping pattern) and pipelines for increased importation of water.

- Energy would be required to carry out any one of the alternatives.

Table 5
TOTAL ENERGY REQUIREMENTS*
FOR ALTERNATIVES, 1970–2020

Alternative	Billions of kilowatt-hours (kWh)
A	26
B	10
C	31
D	22
E	27

*State Water Project water required 4 128 kWh per acre-foot (1 233 m^3); ground water for typical pumping lift of 100 to 350 feet (30.5 to 107 m) requires 102 to 358 kWh per acre-foot (1 233 m^3).

The impact of this increase would be felt most keenly in the areas in which power is generated, which might be outside Ventura County. As Table 5 shows, the overall energy requirement would be the greatest for management alternative C (No Change in Storage), even though it would require the smallest amount of energy for pumping ground water. Conversely, the total energy requirement would be the smallest for B (Maximum Extraction), although its requirement for pumping ground water is the greatest. Because water imported into Southern California via the State Water Project must be lifted a total of 3,550 feet (1 080 m), the energy requirement is greater than that for pumping an equal amount of ground water.*

- Subsidence of the ground surface could take place, because of declining ground water levels. (Declining ground water levels would be the most acute under B: Maximum Extraction.) Subsidence, particularly if it takes place unevenly, could create concern and

*Figure 13 implies that the greatest decline in ground water levels would take place under alternative B (Maximum Extraction). This decline means that more than 2 million acre-feet (2 500 hm^3) of ground water would be used from the 29 million acre-feet (36 000 hm^3) estimated to be in storage.

Photo courtesy Ventura Regional County Sanitation District

ONE OF THE SPREADING GROUNDS supplying the aquifer zones of the Oxnard Plain Basin.

uncertainty among residents and actual danger to structures.

- o Conversely, the less the decline in ground water levels, the smaller the amount of space that would be available in the basins for storing runoff, thus increasing waste to the ocean and flood hazard during heavy rains. C (No Change in Storage) would leave the smallest amount of storage space available in the ground water basins.

- o The combination of recharge of large amounts of imported water and shift in pumping from the Upper to the Lower Aquifer System that is called for under alternative D (Maximum Extraction and Recharge and Changed Pumping Pattern) could create artesian conditions along the coast.

- o The enlarging of the spreading grounds, as would take place under operation of management alternative D (Maximum Extraction and Changed Pumping Pattern), would involve the inundating of land now being used for agriculture.

- o The high TDS content of pumped ground water under operation of B (Maximum Extraction) could mean that the local water managers would have to institute measures to meet the requirements for each beneficial use. For example farmers could use additional amounts of water to maintain crop yield.

Examining Promising Features

After the five alternatives had been evaluated and their impacts analyzed, the features that would lead to the most economical, effective, and environmentally acceptable management could be identified.

As one example of how these features could be combined into a plan for managing the basins, the investigators devised a sixth alternative—called L--which is actually a modification of the original five. It is only one of many possible modifications. Derived from information developed during the detailed study of the original five alternatives, it is based on water elevation projections without the use of the mathematical model. It is presented to illustrate the type of planning that could be considered in the study area.

In general, the provisions of alternativ(L would be:

- o Use the same amount of surface water and reclaimed water as in the other five alternatives.

Photo courtesy Ventura Regional County Sanitation District

STRAWBERRIES are one of the crops produced on the Oxnard Plain of Ventura County.

- o Meet as much of demand as possible with ground water.

- o In the Oxnard Plain, gradually shift pumping so that as soon as possible all water comes from the Lower Aquifer System. (For the study this was set at 1980.) Thus, the fresh water in storage in the offshore portion of the Lower Aquifer System would be put to use, and the Upper Aquifer System, which has been intruded by sea water, would be allowed to refill to repel the intruding sea water.

- o Import no water for recharging the ground water basins or for a sea water intrusion barrier.

- o Import only enough water for direct use to meet the demand not being met with other supplies.

In general, the effects, which were determined without the use of the mathematical models but rather by extending the knowledge obtained from the analyses of the five alternatives, would be the following:

- o Sea water intrusion in the Upper Aquifer System of the Oxnard Plain would be controlled without the need for a barrier. Thus, this cost item would be eliminated.

- o Water would move from the Upper Aquifer System to the ocean, both as subsurface flow and as rising water. If found to be desirable, the rising water could be pumped inland to the spreading grounds for recharging the ground water basins. If this is not done, streamflow would be ensured in the Santa Clara River, and an estuary might be reestablished at the coastline. Because of this condition, little storage space would be left in the Upper Aquifer System for storing runoff.

- o Overall, the amount of ground water in storage would decrease by about the same amount as it would under operation of alternative B (Maximum Extraction). However, more of the decrease would be from offshore aquifers and less from onshore aquifers than would be true under B. The decline in water levels might, in some places, be great enough to introduce the possibility of land subsidence.

- o By shifting all pumping to the Lower Aquifer System in the Oxnard Plain, the average pumping lift would be higher than that required for any of the five management alternatives studied. This estimated average pumping lift in 2020 would be 350 feet (107 m). Thus, the cost of pumping ground water would be greater than that under any of the original five alternatives.

- Nonetheless, total energy requirement (estimated at 7 billion kWh) would be much lower than that for any of the alternatives studied (Table 5). This is because the modification would use a smaller amount of imported water than would any of the original five alternatives.

- Quality of the ground water used in the Oxnard Plain would be better than that used under any of the five management alternatives studied. (Average TDS content in 2020 of water from the Lower Aquifer System is estimated to be 880 mg/l; by comparison, the blended water--from both aquifer systems--that would be used under alternative B would be 1 420 mg/l.)

- The better quality ground water (in comparison with that from the other five alternatives) that would be provided for agricultural use from the Lower Aquifer System would result in higher production with the same amount of irrigation water.

- Use of water from the Lower Aquifer System would also mean better quality water for municipal and industrial use, except for those alternatives that would entirely or largely use imported water (as in E: Selective Use of Water or C: No Change in Storage). Users would see this reflected in savings on soap, water softeners, and bottled water and reduced corrosion of water pipes and heaters.

- As under any plan of management devised for the water resources of Ventura County, some construction would be required. In many cases, new wells would have to be drilled or existing wells deepened if alternative L were implemented. However, the need for additional transmission and storage facilities for imported water would be at a minimum.

- Pumping water from the Lower Aquifer System under the Oxnard Plain could cause a corresponding drop in the water levels in other basins that are in hydraulic continuity with the Lower Aquifer System, such as the Pleasant Valley and East and West Las Posas Basins.

  The water demand in these areas could be satisfied in a number of different ways--by deepening wells, by using reclaimed water for irrigation, by transporting water from the Oxnard Forebay, or by using water imported through the system of the Calleguas Municipal Water District. But however the demand is met, the savings realized from operation of this alternative could be applied to financing the required costs.

- Estimated present worth cost of the variable components of alternative L would be $100.6 million, in contrast with $128.5 million for alternative B and $191.9 million for alternative C (Table 4). When penalty costs for the use of water with high TDS content are added, the present worth cost of alternative L becomes $185.6 million (as compared with $222.2 million for alternative C). Expressed as average annual cost per household, the estimated cost (both variable components and penalty costs) of alternative L is $128.

BIBLIOGRAPHY

1. California Department of Health. Memorandum on "Position on Reclaimed Water Uses Involving Domestic Water Supply." H. J. Ongerth, Chief, Water Sanitation Section, to Bill B. Dendy, Executive Officer, State Water Resources Control Board. September 18, 1973.

2. California Department of Water Resources. "Water Quality and Water Quality Problems, Ventura County". Volumes I and II. Bulletin No. 75. February 1959.

3. ----. "The California State Water Project in 1963-75". Bulletins Nos. 132-1963 through 1975.

4. ----. "Sea Water Intrusion: Oxnard Plain of Ventura County". Bulletin No. 63-1. October 1965.

5. California Department of Water Resources, Southern District. "Hydrologic Procedures Used in the Investigation of Planned Utilization of Water Resources in Ventura County". By Earl Motokane, Assistant Engineer. Technical Information Record 1335-0001. April 1972.

6. ----. "Mathematical Modeling of Water Quality for Water Resources Management". Volumes I and II. Prepared for U. S. Department of Interior, Office of Water Resources Research. District Reports. August 1974.

7. California Water Resources Control Board and Regional Water Quality Control Board, Los Angeles Region. "Tentative Water Quality Control Plan Report, Santa Clara River Basin (4A)". Volumes I and II. June 1974.

8. California Water Resources Board. "Ventura County Investigation". Bulletin No. 12. Volumes I and II. 1953. Revised April 1956.

9. The Metropolitan Water District of Southern California. "Annual Reports". 1939-1974.

10. Orange County Water District. "Water Quality and Consumer Costs". May 1972.

11. U. S. Department of Interior, Bureau of Reclamation. "Sespe Creek Project, California". December 1965.

12. U. S. Department of Interior, Office of Saline Water. "The Economic Value of Water Quality". Prepared by Metcalf and Eddy, Engineers. Research and Development Progress Report No. 770. January 1972.

13. United Water Conservation District. "Report on Proposed Quality Management Pipeline and Oat Mountain Diversion". March 1974.

14. University of California Cooperative Extension. "Guidelines for Interpretation of Water Quality for Agriculture". Jan. 15, 1975.

Technical Information Records prepared for this study:

15. Geologic Formations, Structures and History in the Santa Clara-Calleguas Area by Mike M. Mukae and John Turner, Hydrologists.

16. Aquifer Delineation in the Oxnard-Calleguas Area, Ventura County by John M. Turner, Hydrologist.

17. Effective Base of Fresh Water Reservoir in the Oxnard-Calleguas Area by John M. Turner and Mike M. Mukae, Hydrologists.

18. Evaluation of the Annual Amounts of Precipitation by Earl S. Motokane, Assistant Engineer.

19. Selection of a Base Period by Chan Yoou, Assistant Engineer.

20. Evaluation of Historical Population by Tso Fong Poon, Assistant Engineer.

21. Evaluation of Land Use by Tso Fong Poon, Assistant Engineer.

22. Evaluation of Consumptive Use by Bohdan Romanowski, Assistant Engineer.

23. Evaluation of Surface Water Inflow and Outflow by Bohdan Romanowski and Morey M. Fos-Hati, Assistant Engineers.

24. Evaluation of the Diversion of Streamflow by Tso Fong Poon, Assistant Engineer.

25. Evaluation of Fresh Water Import-Export by W. G. Marty, Water Resources Engineering Associate.

26. Evaluation of Artificial Recharge of Fresh Water by W. G. Marty, Water Resources Engineering Associate.

27. Evaluation of Waste Water by W. G. Marty, Water Resources Engineering Associate.

28. Evaluation of the Effective Base of Fresh Water in Santa Clara River Valley by Stig J. Johanson, Assistant Engineering Geologist.

29. Determination of Transmissibility of the Santa Clara-Calleguas Subarea by Stig J. Johanson, Assistant Engineering Geologist.

30. Evaluation of Ground Water Extractions in Santa Clara-Calleguas Subarea by Tonnis Tempel, Associate Water Quality Engineer, and John S. Mizerak, Assistant Engineer.

31. Evaluation of Specific Yield and Change in Storage of the Santa Clara-Calleguas Subarea by James M. Parsons, Associate Engineering Geologist.

32. Evaluation of Rising Water in the Santa Clara-Calleguas Subarea by Christopher S. Donabedian, Associate Engineer, and Eugene C. Ramstedt, Assistant Engineer.

33. Evaluation of the Incremental User Cost by John Akiyama, Associate Engineer.

34. Technical Information Records (TIR) prepared for study reported in reference 6 above:

Activity Plan and Task Descriptions for Mathematical Modeling of Water Quality for Water Resources Management in the Santa Clara-Calleguas Area. TIR 1335-OWRR-1.

Quality of Domestic Waste Water in the Santa Clara-Calleguas Area. TIR 1335-OWRR-2.

Historical Quality of Industrial Waste Water in the Santa Clara-Calleguas Area. TIR 1335-OWRR-3.

Preliminary Evaluation of the Historical Quality of Ground Water Extracted from the Santa Clara-Calleguas Area. TIR 1335-OWRR-4.

Historical Quality of Surface Water in Santa Clara-Calleguas Area. TIR 1335-OWRR-5.

Movement of Salts in Ground Water: Recharge in the Santa Ana Narrows Basin and the Santa Ana Forebay. TIR 1335-OWRR-6.

Preliminary Evaluation of the Importance of Ion Exchange in Modeling the Total Dissolved Solids in the Santa Clara-Calleguas Area. TIR 1335-OWRR-7.

Effects of Irrigated Agriculture on the Quality of Ground Water in the Santa Clara-Calleguas Area. TIR 1335-OWRR-8.

Preliminary Evaluation of Vertical Zonation of Salinity in the Ground Water of Santa Clara-Calleguas Area. TIR 1335-OWRR-9.

Preliminary Evaluation of Geochemical Effects of Sediments on the Quality of Ground Water in the Santa Clara-Calleguas Area. TIR 1335-OWRR-10.

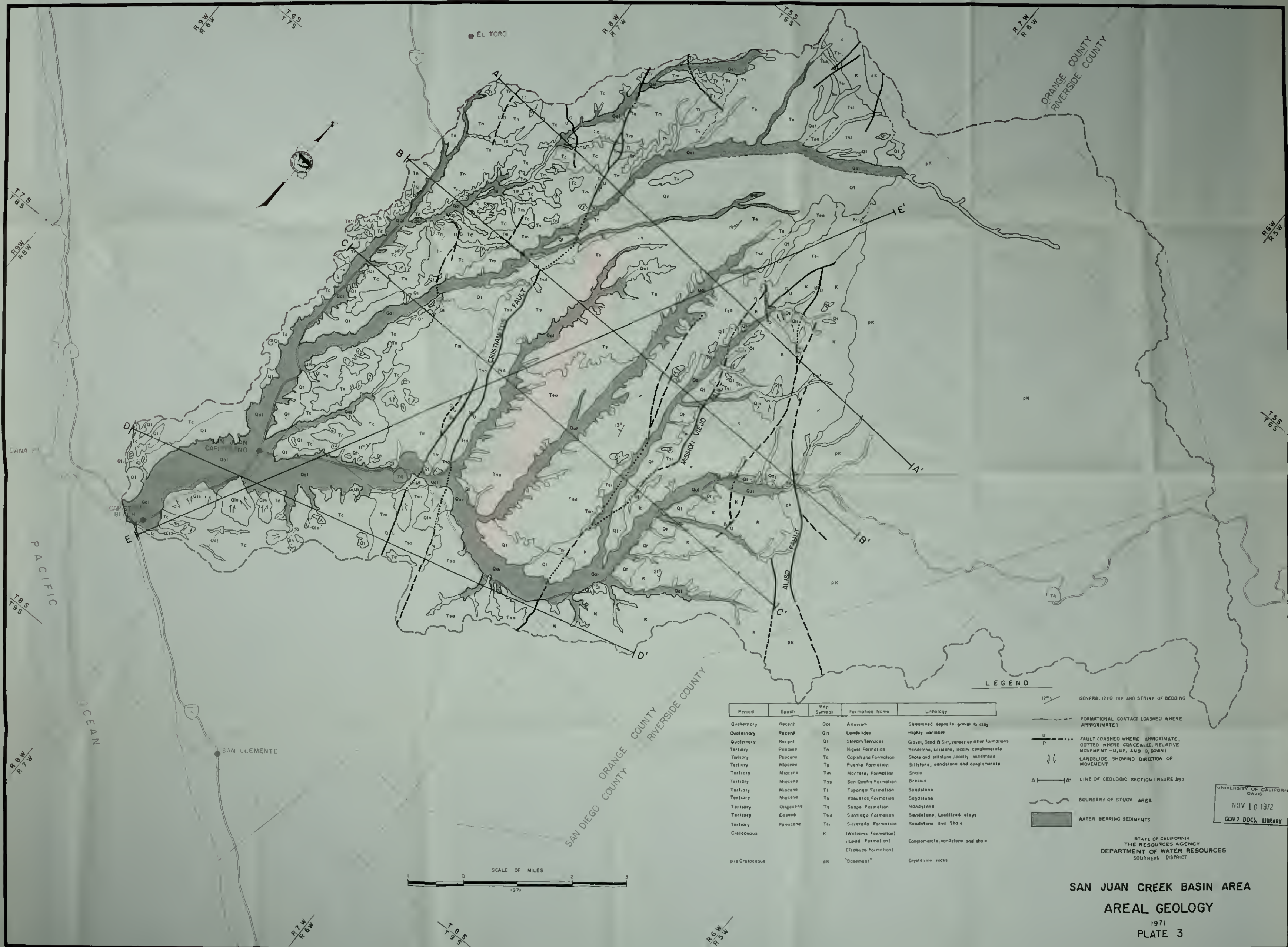
Preliminary Evaluation of the Allocation of Water Supply in the Santa Clara-Calleguas Area. TIR 1335-OWRR-11.

Water Quality Data Base for the Verification of the Mathematical Ground Water Quality Model of the Santa Clara-Calleguas Area, Ventura County. TIR 1335-OWRR-12.

Mathematical Quantity Model of the Santa Clara-Calleguas Area Ground Water System, Ventura County. TIR 1335-OWRR-13.

Preliminary Evaluation of Sea Water Intrusion of Oxnard and Mugu Aquifers in the Oxnard Plain, Ventura County. TIR 1335-OWRR-14.

Preliminary Evaluation of the Geohydrology of the Santa Clara-Calleguas Ground Water Basin Water Quality Study. TIR-1335-OWRR-15.



LEGEND

Period	Epoch	Map Symbol	Formation Name	Lithology
Quaternary	Recent	Qal	Alluvium	Streambed deposits-gravel to clay
Quaternary	Recent	Qls	Landslides	Highly variable
Quaternary	Recent	Qt	Stream Terraces	Gravel, Sand & Silt, veneer on other formations
Tertiary	Pliocene	Tn	Niguel Formation	Sandstone, siltstone, locally conglomerate
Tertiary	Pliocene	Tc	Capistrano Formation	Shale and siltstone, locally sandstone
Tertiary	Miocene	Tp	Puente Formation	Siltstone, sandstone and conglomerate
Tertiary	Miocene	Tm	Monterey Formation	Shale
Tertiary	Miocene	Tso	San Onofre Formation	Breccia
Tertiary	Miocene	Tt	Topanga Formation	Sandstone
Tertiary	Miocene	Tv	Vaqueros Formation	Sandstone
Tertiary	Oligocene	Ts	Sespe Formation	Sandstone
Tertiary	Eocene	Tsa	Santiago Formation	Sandstone, Localized clays
Tertiary	Paleocene	Tsi	Silverado Formation	Sandstone and Shale
Cretaceous		K	(Williams Formation) (Ladd Formation) (Trabuco Formation)	Conglomerate, sandstone and shale
pre Cretaceous		pK	"Basement"	Crystalline rocks

12° GENERALIZED DIP AND STRIKE OF BEDDING

FORMATIONAL CONTACT (DASHED WHERE APPROXIMATE)

U D FAULT (DASHED WHERE APPROXIMATE, DOTTED WHERE CONCEALED, RELATIVE MOVEMENT—U, UP, AND D, DOWN)

LANDSLIDE, SHOWING DIRECTION OF MOVEMENT

A A' LINE OF GEOLOGIC SECTION (FIGURE 39)

BOUNDARY OF STUDY AREA

WATER BEARING SEDIMENTS

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN JUAN CREEK BASIN AREA

AREAL GEOLOGY

1971

PLATE 3

3624